North Carolina Salt Marsh Action Plan

Protect, restore, and facilitate the migration of salt marshes in North Carolina to minimize loss of function, benefits, and acreage through 2050 and beyond.

J Lee (Instagram: @growingwilder)

May 2024

North Carolina Coastal Federation
Working Together for a Healthy Coast

SOUTH ATLANTIC SALT MARSH INITIATIVE

Executive Summary

About the North Carolina Salt Marsh Action Plan

This North Carolina Salt Marsh Action Plan (NC SMAP) details a five-year strategy to protect, restore, and allow for the migration of salt marshes in coastal North Carolina to minimize the loss and degradation of their existing ecological, economic, and cultural functions. These salt marshes are regularly and irregularly flooded by lunar and wind tides, and for the purposes of this plan, are defined as all estuarine wetlands (salinities ≥ 0.5 parts per thousand). North Carolina has one of the largest and most productive estuarine systems in the United States. Its nearly 2.3 million acres of diverse coastal habitats support fisheries and wildlife, protect and provide socio-economic benefits to coastal communities, facilitate military readiness, and foster cultural and spiritual values and traditions. Salt marshes provide a wide array of ecosystem services, including essential fish habitats, water quality enhancements, flood protection for adjacent communities, and climate mitigation by sequestering carbon.

The North Carolina coast has approximately 220,000 acres of salt marshes, a critical component of one of the country's largest remaining expanses of salt marsh. There are about one million acres of salt marshes along the South Atlantic coast from North Carolina to the Atlantic coast of northern Florida, and this plan is coordinated with region-wide efforts to protect and restore this vast marsh ecosystem. Persistent and emerging threats to current and future salt marshes are numerous, including degradation by incompatible land and water uses, boat wakes, as well as more intense and wetter storms and sea level rise (SLR) resulting from climate change. These threats and impacts must be addressed effectively to retain and reclaim ecosystem services that have already been impacted and to avert projected future losses that could fundamentally degrade and endanger fisheries and water quality, as well as the resiliency, economy, and cultural heritage of coastal communities.

The threats to salt marshes require urgent and effective actions. In response to this need, the South Atlantic Salt Marsh Initiative (SASMI) was formed in 2021 under the leadership and guidance of The Pew Charitable Trusts (Pew) and the Southeast Regional Partnership for Planning and Sustainability (SERPPAS). As a regional initiative, SASMI brings together more than 350 diverse partners, including leaders from federal, state, and local agencies and stakeholders from academia, non-governmental organizations (NGOs), and the community. With the goal of preserving and enhancing the existing million acres of salt marsh between North Carolina and the northern Atlantic coast of Florida, SASMI released *Marsh Forward: A Regional Plan for the Future of the South Atlantic Coast's Million-Acre Salt Marsh Ecosystem* (SASMI Plan) in May 2023.

The NC SMAP aligns with the regional SASMI Plan and brings together local, state, and federal stakeholders from academia, governmental agencies, communities and NGOs to prioritize actions and make the best use of available resources within North Carolina. It is meant to further other efforts aimed at protecting the coastal environment and to include strategies and recommendations to increase carbon sequestration and resilience of coastal habitats and communities in North Carolina. The NC SMAP is the result of the collaborative efforts and valuable insights of numerous local experts and stakeholders. The North Carolina Coastal Federation hosted three workshops during the summers of 2022 and 2023 that were vital for establishing fundamental elements of the plan and refining the recommended actions.

The NC SMAP leverages spatial analysis and diverse stakeholder expertise to identify practical actions for all stakeholders and entities working on a range of actions to maintain or enhance salt marshes through 2050 as the climate changes. Projections generated from Warnell, et al. 2020, which utilizes elevation and SLR data, estimate that North Carolina could see a net gain of about 180,000 acres of salt marsh by 2050 under an intermediate SLR scenario, assuming no major developmental or geological changes. These estimates show, however, that the gains and losses of salt marsh will not be experienced equally along the coast. The southern coast, with its higher elevation and coastal development, will experience significantly more salt marsh loss than the lower-lying, less developed central and northern coasts. This geographical dichotomy shaped the strategies

outlined in the NC SMAP, focusing on minimizing salt marsh loss, restoring existing marsh, facilitating migration, and pursuing cross-cutting actions to facilitate overall implementation.

Goal

The overarching goal of the NC SMAP is to protect, restore, and facilitate the migration of salt marshes in North Carolina to minimize loss of function, benefits, and acreage through 2050 and beyond.

Strategies and Implementation

In coordination with the SASMI Plan, there are three guiding strategies of the NC SMAP necessary to achieve the overarching goal. These strategies detail approaches to conserve, restore, and facilitate the migration of salt marshes based on the needs and projections of North Carolina. Each strategy has multiple objectives and recommended actions for implementation. Where appropriate and feasible, the objectives and actions are aligned and coordinated with those of the SASMI Plan. Finally, for each action, the outputs and intended results of its successful completion have been identified. The **three guiding strategies** are:

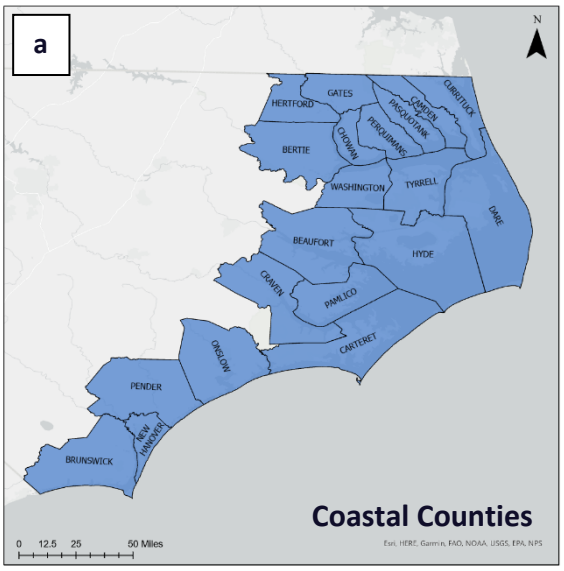
The NC SMAP includes **five key features**, in which it:

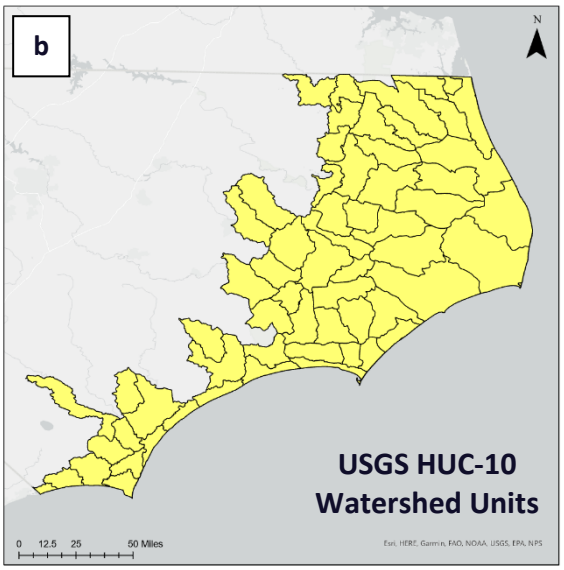
1	Identifies current and emerging threats to salt marshes
2	Devises strategies that will effectively address identified threats relying upon the best available science and expertise that can be obtained
3	Promotes widespread and meaningful public understanding and demand for achieving the goal of this plan
4	Devises way to engage stakeholders from all walks of life in taking ownership of advancing the plan's recommended actions
5	Outlines a 5-year guidance to support annual strategic planning, monitoring, evaluating success, and adapting the plan as needed to address emerging challenges and needs

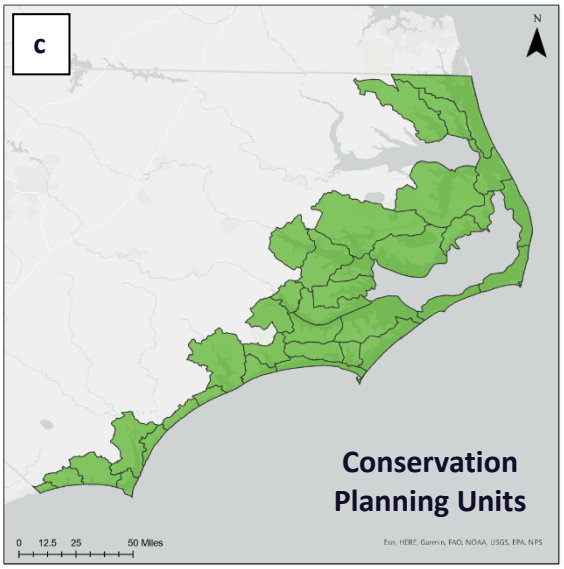
Implementation of the NC SMAP will be a collaborative and complementary effort. The new Salt Marsh Steering Committee (SMSC), which also serves as the North Carolina State Implementation Team for the SASMI Plan, works with partners and stakeholders from across the state to put the NC SMAP into action, while engaging target audiences, supporting ongoing efforts, and sharing information regularly. The NC SMAP is intended to guide priority salt marsh conservation- and migration-focused actions over the next five years (2024-2029) using projections of change to salt marsh extent, health, and function from land use and climate change through the year 2050. Each year, a strategic implementation plan is developed to identify priority locations, key partners, necessary courses of action, specific goals, clear metrics of success for accomplishing the plan objectives, and track progress. The SMSC meets regularly to provide updates, discuss collaboration needs, and assign next steps toward the implementation of the recommended actions. The SMSC also continue to collaborate with SASMI leadership, coalition members, and others to further implement relevant actions outlined in the SASMI Plan. After five years, the NC SMAP will be revaluated, updated, and re-released to ensure that the recommended actions and guidance are always following the best available science and accurately fulfilling the needs for coastal North Carolina.

Geographic Scope

The NC SMAP covers the entire coast of North Carolina's coastal counties **(a)**. The plan divides the region into smaller units based on the US Geological Survey's 10-digit hydrologic unit code (HUC-10) watershed units directly connecting to estuarine surface waters **(b)**. The plan focuses on those HUC-10s in which salt marsh is currently present or is projected to exist by 2050 under intermediate SLR predictions of approximately 1.5 feet. These HUC-10s were then trimmed and amended into the plan's conservation planning units (CPUs) based on jurisdictional and ecological needs **(c)**.



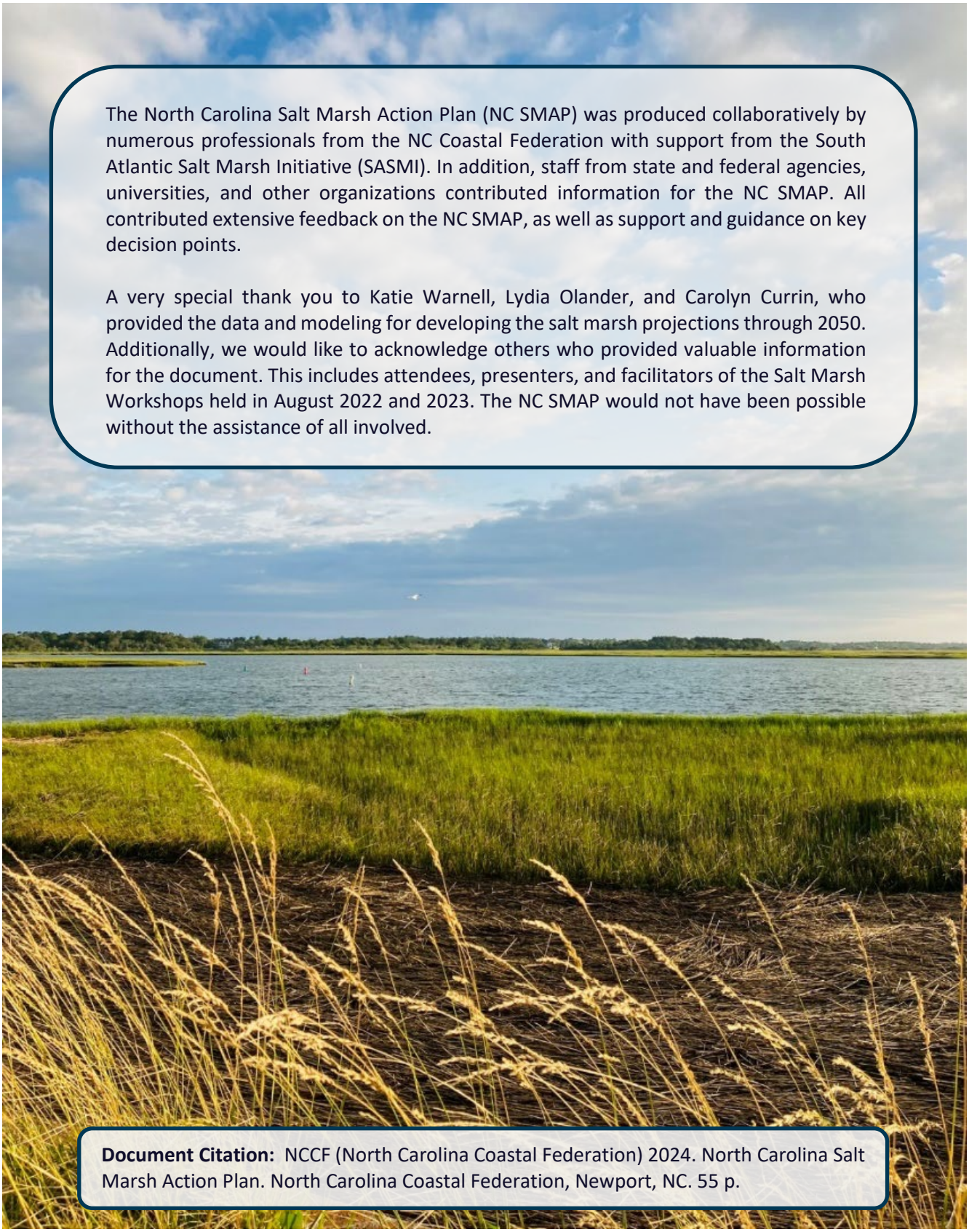




Acknowledgments

The North Carolina Salt Marsh Action Plan (NC SMAP) was produced collaboratively by numerous professionals from the NC Coastal Federation with support from the South Atlantic Salt Marsh Initiative (SASMI). In addition, staff from state and federal agencies, universities, and other organizations contributed information for the NC SMAP. All contributed extensive feedback on the NC SMAP, as well as support and guidance on key decision points.

A very special thank you to Katie Warnell, Lydia Olander, and Carolyn Currin, who provided the data and modeling for developing the salt marsh projections through 2050. Additionally, we would like to acknowledge others who provided valuable information for the document. This includes attendees, presenters, and facilitators of the Salt Marsh Workshops held in August 2022 and 2023. The NC SMAP would not have been possible without the assistance of all involved.



Document Citation: NCCF (North Carolina Coastal Federation) 2024. North Carolina Salt Marsh Action Plan. North Carolina Coastal Federation, Newport, NC. 55 p.

Table of Contents

Abbreviations and Acronyms

CAMA	Coastal Area Management Act
CHPP	Coastal Habitat Protection Plan
CO_2	Atmospheric carbon
CPU	Conservation planning unit
DCM	Division of Coastal Management
DoD	Department of Defense
DOT	Department of Transportation
ENCSL	Eastern NC Sentinel Landscape
EO	Executive Order
HUC-10	10-digit hydrologic unit code
IMM	Integrated Marsh Management
MMT CO_2e	Million metric tons of CO_2 equivalent
NC DEQ	NC Department of Environmental Quality
NC SMAP	NC Salt Marsh Action Plan
NC WRC	NC Water Resources Commission
NCCF	NC Coastal Federation
NCORR	NC Office of Recovery and Resiliency
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OMWM	Open Marsh Water Management
SAC	Stakeholder Advisory Committee
SASMI	South Atlantic Salt Marsh Initiative
SAV	Submerged aquatic vegetation
SERPPAS	Southeast Regional Partnership for Planning and Sustainability
SET	Surface Elevation Table
SLR	Sea level rise
SMSC	Salt Marsh Steering Committee
SWI	Saltwater intrusion
US ACE	US Army Corps of Engineers
US EPA	US Environmental Protection Agency
US FWS	US Fish and Wildlife Services
USDA	US Department of Agriculture

List of Tables

List of Figures

1. Introduction

1.1. Background

The U.S. Environmental Protection Agency (EPA) defines wetlands as "areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season."[1] There are different types of wetlands due to variable conditions (i.e., regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, human disturbance) with two general categories of wetlands that are recognized: coastal or tidal wetlands and inland or non-tidal wetlands.[1] Because there are multiple classification systems and terms used to describe different types of wetlands, this plan takes a similar approach as identified in the 2021 NC Coastal Habitat Protection Plan (CHPP) Amendment that used a simplified Cowardin System splitting wetlands within the CHPP region into two broad classes, palustrine wetlands (freshwater) and estuarine wetlands (salinities ≥0.5 parts per thousand - ppt)[2]. For the purposes of this plan, salt marsh is defined as all estuarine wetlands in North Carolina.

Approximately 95% of North Carolina's remaining 4 million acres of wetland resources are located in the state's Coastal Plain region[3]. While most of these are freshwater wetlands, North Carolina also has an extensive span of salt marsh that are part of the state's more than 2.3-million-acre estuarine system. Salt marshes are regularly or irregularly flooded by lunar or wind tides, generating a unique ecosystem with thick mats of grasses, sedges, and rushes that, over time, form peat soils as their foundation. This distinctive array of vegetation provides a suite of largely irreplaceable ecosystem services, which are forfeited when salt marsh is degraded or destroyed.

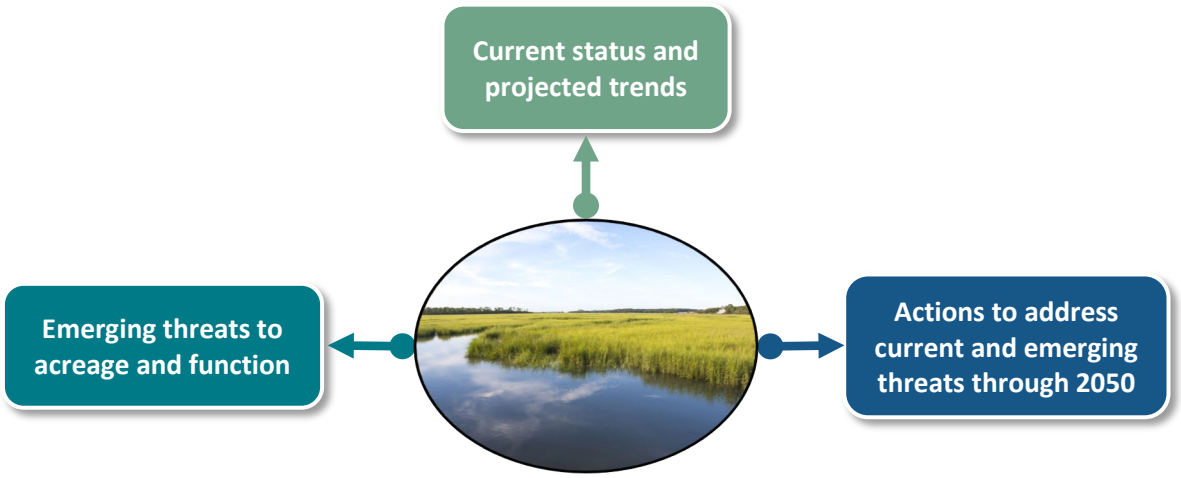
The South Atlantic coast of the United States harbors nearly one million acres of salt marsh, spanning from North Carolina through the northern Atlantic coast of Florida. Currently, there are approximately 220,000 acres of salt marsh along the North Carolina coast. These marshes, however, face many localized and widespread threats to their function and existence. Past trends and future projections under a changing climate paint a bleak picture if concerted action is not taken to embrace opportunities at our collective disposal to conserve and restore existing salt marshes and facilitate their ability to adapt to climate change. Fortunately, North Carolina stands well positioned to face the challenges of minimizing loss of salt marsh acreage and functions through 2050 due to the state's investments in climate adaptation, a wealth of expertise from government, nonprofits, and universities, and forward momentum in implementing nature-based climate adaptation solutions.

In response to the need for effective actions for addressing threats to salt marsh, the South Atlantic Salt Marsh Initiative (SASMI) was formed in 2021 under the leadership and guidance of The Pew Charitable Trusts (Pew) and the Southeast Regional Partnership for Planning and Sustainability (SERPPAS). As a regional initiative, SASMI brings together more than 350 diverse partners, including leaders from federal, state, and local stakeholders from academia, government agencies, NGOs, and the community. With the goal of preserving and enhancing the existing one million acres of salt marsh between North Carolina and the northern Atlantic coast of Florida, SASMI released *Marsh Forward: A Regional Plan for the Future of the South Atlantic Coast's Million-Acre Salt Marsh Ecosystem* (SASMI Plan) in May 2023.

To effectively implement the SASMI Plan at the state level in North Carolina, the North Carolina Coastal Federation (NCCF; the Federation) led the development of this North Carolina Salt Marsh Action Plan (NC SMAP). This plan is the result of the collaborative efforts and valuable insights of numerous local experts and stakeholders. To foster this collaboration, the Federation hosted three workshops during the summers of 2022 and 2023 (Appendix A). These workshops were vital for establishing fundamental elements of the plan and refining the recommended actions detailed in Section 3.

The NC SMAP further implements and aligns with the SASMI Plan and details a five-year strategy to protect, restore, and allow for the migration of salt marshes in coastal North Carolina so that their existing ecological, economic, and cultural functions are not degraded or lost. Bringing together local, state, and federal

stakeholders and experts, it details priority actions and makes the best use of available resources. The NC SMAP leverages spatial analysis and diverse stakeholder expertise to identify practical actions for communities, organizations, government agencies, lawmakers, and other entities working on a range of actions throughout the coast to maintain or enhance salt marshes through 2050 as the climate changes. Building on and in conjunction with other planning efforts, the NC SMAP outlines:



The NC SMAP is meant to further other efforts aimed at protecting the coastal environment and that include strategies and recommendations to increase carbon sequestration and resilience of coastal habitats and communities in North Carolina. Other efforts include the North Carolina Coastal Habitat Protection Plan (CHPP), which is led by the North Carolina Department of Environmental Quality (NC DEQ), who is charged with development, updating, and implementation of the plan (Table 1). The overarching goal of the CHPP is the long-term enhancement of coastal fisheries through habitat protection and enhancement efforts. The 2021 Amendment to the CHPP included sections specific to wetland conservation and restoration and impacts from climate change that are affecting all coastal habitats and species throughout North Carolina (Table 1).

Additional efforts in North Carolina that include strategies and recommendations to increase carbon sequestration and resilience of coastal habitats and communities include the 2020 North Carolina Climate Risk Assessment and Resilience Plan (2020 Resilience Plan) and the 2020 Natural and Working Lands Action Plan (Table 1). These were the result of Governor Roy Cooper's 2018 Executive Order 80 (EO80) - North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy directing all cabinet agencies to integrate climate adaptation and resiliency planning into their policies, programs, and operations. The EO80 calls for action aimed at adaption and mitigation efforts to enhance resilience against the impacts of climate change. The Currituck Sound Coalition Marsh Conservation Plan was launched in 2021 that outlined five strategies intended to yield near-term benefits for marshes in northeastern North Carolina and will be revisited every three years to update. Governor Cooper's 2022 Executive Order 246 (EO246) - North Carolina's Transformation to a Clean, Equitable Economy, includes priorities that builds on the Governor's previous actions supporting clean energy, climate change, and environmental justice. The EO246 addresses adaptation and resilience and requires integrating climate and equity into government-wide actions when implementing EO80 and the state's 2020 Resilience Plan. Governor Cooper's 2024 Executive Order 305 (EO305) - An Order to Protect and Restore North Carolina's Critical Natural and Working Lands, provided that North Carolina encourage, facilitate, plan, coordinate, and support federal, state, local, and private land protection and restoration efforts. The following goals were set by EO305 to be achieved by 2040: permanently conserve one million new acres of natural lands (with a focus on wetlands), restore or reforest one million new acres of forests and wetlands, and plant one million trees in urban areas. The North Carolina Priority Climate Action Plan (PCAP) was launched in 2024 for phase 1 of the EPA Climate Pollution Reduction Grants (CPRG) program that offers funding to states, local governments, tribes, and territories to develop and implement plans aimed at reducing greenhouse gas (GHG) emissions and other harmful air pollutants. The NC PCAP priority measures include natural and working

lands to pursue policy, programs, and projects to protect and restore high-carbon habitats across the region. This includes protecting and restoring high-carbon coastal habitats and peatlands (Table 1). Table 1 contains a non-exhaustive list of information on additional efforts in North Carolina (Table 1).

Table 1. Non-exhaustive list of existing plans and policies that include items supporting the actions in the North Carolina Salt Marsh Action Plan by year.

Title	Description	Year
Executive Order 80	North Carolina's commitment to address climate change and transition to a clean energy economy integrating climate adaptation and resiliency planning into policies, programs, and operations.	2018
Natural and Working Lands Action Plan	A plan to identify and create opportunities for North Carolina's natural and working lands that sequester carbon, build ecosystem and community resilience, provide ecosystem benefits, and enhance the economy.	2020
NC Climate Risk Assessment and Resilience Plan	A plan directed by Executive Order 80 to develop resilience strategies to adapt to climate change.	2020
Action Plan for Nature-Based Stormwater Strategies	A plan for promoting natural designs that reduce flooding and improve water quality.	2021
Currituck Sound Coalition Marsh Conservation Plan	A plan that serves as a starting point in an ongoing process of collaborative conservation planning and action to increase community and ecosystem resilience to climate change and other threats through enhanced collaboration and partnership on nature-based initiatives.	2021
NC Coastal Habitat Protection Plan 2021 Amendment	A resource and guide to assist the Marine Fisheries, Environmental Management, and Coastal Resources commissions in development of goals and recommendations for protecting fisheries habitat in North Carolina.	2021
NC Wetland Program Plan	Updates to the North Carolina Wetland Program Plan with wetland goals and specific activities, divisions addressing them through 2025, appropriate EPA Core Element Framework actions, and stakeholder members and interests.	2021
The Oyster Blueprint 2021-2025	A plan for oyster restoration and protection focusing on ways to enhance native oyster populations, addressing specific stakeholder concerns or documented threats to support healthy and productive coastal waters and habitats.	2021
APNEP Comprehensive Conservation and Management Plan	Albemarle-Pamlico National Estuary Partnership 2012-2022 Comprehensive Conservation and Management Plan to ensure these resources are sustained and available to future generations.	2022
Executive Order 246	North Carolina's transformation to a clean, equitable economy that builds on previous actions supporting clean energy, climate change, and environmental justice.	2022
Executive Order 305	An order to protect and restore North Carolina's critical natural and working lands including wetlands.	2024
NC Priority Climate Action Plan	A plan for the US Environmental Protection Agency's Climate Pollution Reduction Grants program with natural and working lands priority measures to pursue policy, programs, and projects to protect and restore high-carbon habitats.	2024
Uniform Floodplain Management Policy for State Property	A policy that provides for the sound management of state-owned properties as they relate to potential flood hazards by requiring the consideration of nature-based infrastructure, flooding, and sea level rise in designs.	2024

1.2. Impetus for Marsh Conservation Efforts

Salt marshes are enormously important to the health and productivity of the coastal environment, economy, and way of life. They provide cross-cutting benefits at no cost, but the scale of projected salt marsh loss and potential gain along the North Carolina coast (Section 2) could fundamentally alter these systems. If damage to the marsh is not prevented or reversed, or if successful migration cannot be facilitated, the loss of this natural resource could severely degrade the vibrancy and livability of our coast and the communities it supports, resulting in the forfeiture of invaluable ecosystem services and the unique appeal of the North Carolina coast (Section 3).

1.2.1. Values and Services

Salt marshes offer many benefits that not only better the communities around them but also intrinsically benefit the natural ecosystems. The interconnectivity and regionally specific needs of coastal habitats and nearby communities make it difficult and seemingly impractical to calculate a single dollar-per-acre value of salt marshes. However, valuations of selected wetland ecosystem services (e.g., storm protection, erosion protection, and water quality enhancement) estimate monetary values for tidal marsh at approximately $78,000 per acre per year[4]. If these global averages are applied to North Carolina's 220,000 acres of salt marsh, the anticipated benefit will exceed $17 billion each year.

The North Carolina Division of Mitigation Services has placed a price tag on the value of an acre of salt marsh that is restored for compensatory mitigation. Anyone seeking to buy credits to offset unavoidable losses must pay $560,000 per acre of salt marsh[5]. This value helps to illustrate the actual overall contribution of salt marshes to both our coastal environment and economy. Using this mitigation price per acre, the real estate value of salt marshes in the state totals more than $123 billion.

Generally, salt marshes provide three classes of services: provisioning (i.e., direct extraction of goods and materials from the ecosystem), cultural (i.e., spirituality, recreation, tourism, health, well-being), and regulating (i.e., coastal protections, climate regulation, water quality management)[6,7]. Salt marshes worldwide offer varying levels of each service type, and they are all vital to the larger interconnected ecosystem of humans and nature that they comprise.

1.2.1.1. Provisioning Services

Wetlands have been referred to as *nature's supermarkets* owing to the expansive variety of resources and biodiversity they provide and support[8]. Salt marshes, specifically, are highly productive ecosystems with valuable resources and habitats supporting many ecologically and economically important wildlife and plant species. In North Carolina, over 70% of the wildlife on federal or state lists of endangered, threatened, or special concern species, such as the saltmarsh sparrow (*Ammodramus caudacutus*), are wetland dependent[9,10]. Furthermore, many fish and marine invertebrate species utilize the warm, shallow marsh waters as nurseries and feeding grounds. More than 90% of North Carolina's commercial fisheries landings and 60% of its recreational harvest consist of species dependent on estuarine habitats, like wetlands and salt marshes[11]. This ideal habitat provides a safe, resource-rich environment to support the growth and development of many environmentally and commercially important species and aids in the recruitment process for continued and future growth.

1.2.1.2. Cultural and Spiritual Services

Salt marshes offer appreciable cultural and spiritual ecosystem services that enhance the socio-economic well-being of coastal communities and visitors. They support a suite of activities, including recreation, tourism, and education, all of which promote healthy lifestyles, enable engagement with nature, have no or minimal environmental impact, create jobs, and, in some cases, generate funds used for conservation. Over one-third of all adults in the United States participate in recreational activities within wetlands, including kayaking, boating, fishing, oystering, clamming, hunting, bird watching, and wildlife photography[12]. Such engagement with nature

has been shown to improve cognitive function and emotional well-being[13]. Additionally, there is a demonstrated tie between nature and psychological well-being, including stress relief, perceived health, sense of self, and social relationships[14].

Not only do these activities support the well-being of coastal residents, but coastal recreation and tourism also support tens of thousands of jobs and infuse more than one billion dollars annually into North Carolina's economy[15]. The purchase of a fishing, hunting, or trapping license from the North Carolina Wildlife Resources Commission (NC WRC) directly funds conservation programs and projects[16]. Salt marshes support many recreational activities that attract visitors to North Carolina's coastal counties, such as fishing, seafood, ecotourism, and swimming. Of the top ten counties in terms of average per capita economic contribution derived from tourism, four are coastal counties (Dare, Hyde, Currituck, and Carteret). In Dare County, which ranks first in the state for per capita economic contribution from tourism, tourism contributes over $27,000 on average per year per resident[2].

Moreover, wetlands hold many historical and contemporary spiritual connections. They often serve as pilgrimage sites and sources of spiritual fulfillment. The waters within these wetlands are utilized for healing purposes and various rituals. The spirituality of indigenous communities worldwide is frequently tied directly to the presence of spirits within wetlands and their surrounding ecosystems. Other faiths, such as Buddhism, Judaism, Christianity, and Islam, tend to perceive wetlands as integral parts of divine creation. The religious values associated with these faiths view the environment's spiritual significance as stemming from its role in a godly creation. Rather than considering natural elements as infused with spirits that warrant reverence and respect, these faiths emphasize the belief that the environment was created by God for humanity to manage responsibly and often opt to locate places of worship within the wetlands[17].

1.2.1.3. Regulating Services

Salt marshes are important regulators of physical and biogeochemical processes in the estuarine environment. These services buffer shorelines from erosion, protect communities from impacts of storm surge flooding, regulate water quality, and help regulate climate change through the removal and sequestration of carbon from the atmosphere.

Natural Hazard Mitigation

Salt marshes can drastically reduce storm-related damage to coastal property and infrastructure through the control and reduction of shoreline erosion, flooding, and storm surge. The dense vegetation binds soil and traps suspended sediments, holding the shoreline in place. Additionally, the intricate below-ground biomass strengthens the substrate, further reducing erodibility[18,19]. In fact, one study found that, over a four-decade period, unvegetated shoreline types in Cedar Island, NC, eroded at roughly twice the rate as those with estuarine emergent wetlands[20].

Similarly, salt marsh vegetation absorbs the wave energy induced by boat wake, winds, and storms, reducing the force with which it strikes the shoreline. As water flows through salt marsh vegetation, friction caused by above-ground biomass reduces wave energy dramatically[21]. This drag from the vegetation inflicted on water flow is effective enough that even relatively narrow salt marshes (<10m wide) have been shown to reduce wave heights by 50-80%[18,22].

Salt marshes can also play a vital role in the protection and preservation of barrier islands. Backbarrier salt marshes, which lie directly landward of barrier islands, are created and reinforced by the natural wind- and storm-driven transport of sediments from the beaches and dunes. As the marshes grow and strengthen, they help stabilize the barrier island. By providing a natural platform or perch onto which the beach and dunes can migrate, the barrier system can widen, thus slowing its landward migration and hindering storm breaching. Consequently, this symbiotic relationship between the backbarrier marshes and barrier islands has been

explored in depth for its coastal systems management capabilities. By adding or enhancing existing backbarrier marshes, which can then be reinforced through overwash and sediment transport, the marshes can then act as a stabilizing force, thus increasing resilience and protecting the crucial barrier islands[23].

Many studies have worked toward estimating the monetary value of storm, flood, and erosion protection provided by salt marshes and wetlands. For instance, using a replacement cost valuation method, researchers estimated the shoreline stabilization value of tidal wetlands in Florida to be $50 per linear foot[24]. One analysis of 34 major hurricanes impacting the United States estimated that the total storm protection value of wetlands in the US was more than $23 billion per year. The analysis also found that, on average, each acre of wetland lost resulted in an additional $13,000 in storm-related damages[25]. Another study showed that the presence of temperate coastal wetlands in the Northeastern United States saved more than $625 million in flood damages following Hurricane Sandy in 2012[26]. One recent analysis found that one square mile of wetland provided more than $2.5 million of storm protection in eight of the 20 North Carolina coastal counties[27]. This value increased about ten-fold in highly developed New Hanover County, where the wetlands were valued at approximately $25 million per square mile in storm protection.

Water Quality Enhancement

As the *kidneys of the landscape*, healthy salt marshes are often the terminal biofilter through which surface waters pass before entering estuarine waters[8]. They are highly efficient at trapping the suspended solids and assimilating excess nutrients that increase turbidity and contribute to coastal eutrophication. As water flows over salt marshes, it is slowed by above-ground vegetation, allowing any suspended sediments to settle out. As a result, less sediment reaches the receiving waters, decreasing turbidity, increasing light penetration to submerged aquatic vegetation (SAV), and improving the health and survivorship of filter-feeding organisms. Additionally, sediment-bound pollutants (e.g., phosphorus and heavy metals) are sequestered within salt marsh soils, and nutrients (e.g., nitrogen and phosphorus) are assimilated by salt marsh plants and microorganism communities[28]. Indeed, studies have shown that salt marshes are capable of assimilating virtually 100% of ambient nitrate loads from coastal stormwater[29]. As such, salt marshes are fundamental in the reduction of eutrophication-caused harmful algal blooms, which can negatively impact wild harvest fisheries, mariculture, coastal tourism, and property values, leading to tens to hundreds of millions of dollars in losses[30].

Carbon Sequestration

Perhaps one of the most paramount services salt marshes and other vegetated coastal habitats (e.g., seagrasses, mangroves, macroalgae) provide is their ability to mitigate climate change through the sequestration of vast amounts of carbon in their above- and below-ground biomass and soils[31]. Atmospheric carbon, in the form of CO_2, is assimilated into salt marsh plant biomass, becoming trapped within the complex root system and, ultimately, buried below the sediment along with additional sources of organic carbon, often at concentrations 30-50x greater than those found in terrestrial forests[32]. Decomposition occurs slowly within the low-oxygen soils of the tidal marshes, allowing carbon to stay sequestered in the sediment for centuries to millennia as long as the habitat remains undisturbed[33].

These vegetated coastal habitats rank globally among the densest carbon sinks[34]. Despite comprising just 0.2% of the ocean surface worldwide, vegetated coastal habitats collectively constitute 50% of carbon burial in marine sediment, also known as 'blue carbon,' and, thus, play a significant role in mitigating the effects of global climate change[35,34]. The estimated carbon stock within contiguous US salt marshes is about 640 million metric tons of CO_2 equivalent (MMT CO_2e)[36,37]. In North Carolina, salt marshes alone store an estimated 64 MMT CO_2e and sequester an additional 200,000 MMT CO_2e each year[38]. Simultaneously, salt marsh can reduce additional CO_2e through uptake and subsequent removal from the atmosphere. For example, coastal wetlands throughout the US removed 4.8 MMT CO_2e from the atmosphere in 2019[39].

The sheer capacity to which these coastal habitats can sequester and store carbon is impressive and beyond essential. Those that can withstand the pressures of rising sea levels and other anthropogenic threats and

continue to thrive have a near-limitless capability to sequester carbon[40]. However, this capacity ultimately depends on their long-term survival[41]. Due to the large quantity and long lifetime of CO_2 emitted into the atmosphere, it has been found that carbon must remain sequestered within the wetlands for at least a century to be considered an effective climate change defense[42,43]. As such, the loss of salt marsh would not only forfeit future carbon sequestration services but also emit some of the carbon stored over millennia back into the system.

The 2020 Resilience Plan acknowledges the essential service offered by salt marshes and their distinction of being among the highest vegetated habitats to sequester carbon per unit area. This plan, which, as directed by EO80, is the state's most comprehensive effort to date to address North Carolina's vulnerability to climate change, observes that incentivizing marsh conservation, marsh migration corridor protection, and active wetland restoration efforts are critical for coastal wetlands to continue sequestering greenhouse gases and fighting against the effects of climate change[44].

1.2.2. Threats

Coastal wetlands worldwide have lost approximately 46.4% of their area since their historic maxima[45]. Historical drivers of salt marsh loss include conversion to other land use types (e.g., agriculture, development), ditching, eutrophication, and sediment supply deficiencies. Before the 1980s, thousands of acres of wetlands had been drained and converted to agricultural lands. Since then, land use has shifted to urban and rural development[46,47]. While Section 404 of the US Clean Water Act affords protection to wetlands connected to navigable waters of the US and has reduced direct conversion of salt marshes, eutrophication and sediment supply still remain significant drivers of salt marsh loss.

Further, despite reductions in wetland loss in recent decades, they are still disappearing at alarming rates. From 2000 to 2019, an area larger than two standard soccer pitches (about 3.5 acres or 14,000 m^2) was lost hourly worldwide. Including the natural gain and recovery throughout this period, this resulted in a net loss of about 360,000 acres (1450 km^2) of salt marsh in 20 years[48]. That loss is more than 1.5 times greater than all the salt marshes currently in North Carolina (approximately 220,000 acres). These more recent losses are primarily driven by such threats as increased stormwater runoff and pollution, direct fill and destruction, boat wake-induced erosion, marine debris, and climate change, particularly accelerating sea level rise (SLR). If left unaddressed, these threats will continue to pose compounding and substantial threats to the health and persistence of salt marshes globally.

1.2.2.1. Human-Induced Environmental Impacts

Development within the 20 coastal counties of North Carolina is increasing significantly. The North Carolina Office of State Budget and Management reported a nearly 10% increase in population from 2010-2019[49]. Furthermore, many coastal North Carolina counties are projected to increase by more than 16-30% between 2019-2039.

While Section 404 of the US Clean Water Act, the North Carolina Coastal Area Management Act (CAMA), and the North Carolina Dredge and Fill Act have protected salt marshes in North Carolina by significantly reducing draining, filling, and other direct disturbances, loss rates can be significantly higher in areas of high population growth and development in coastal zones[50] because of the indirect effects of adjacent development and working lands. Namely, increases in impervious surfaces that accompany development and its supporting infrastructure dramatically increase the quantity and velocity of stormwater reaching estuarine systems, including salt marshes. For example, one acre of conventional parking lot produces 16 times the runoff from one acre of meadow[51]. This increased stormwater brings pollutants in the form of sediment, nutrients (e.g., nitrogen and phosphorus), metals, pesticides, and hydrocarbons. While salt marshes can assimilate background and even enriched levels of nutrients, eutrophication of salt marshes can increase above-ground biomass and decrease

bank-stabilizing below-ground biomass, resulting in salt marsh collapse and conversion to unvegetated open water[52].

Furthermore, as the coast has developed, property owners have sought to fortify their shoreline and landward property. Living shorelines, a nature-based solution for shoreline stabilization, not only provide erosion control, they also provide numerous benefits to fish habitat, salt marsh restoration, oyster restoration, water quality improvement, and enhancing coastal resilience (Figure 1). Historically and at present, bulkheads have been the overwhelmingly dominant shoreline protection strategy (Figure 2). Vertical shoreline armoring structures, including bulkheads, have been shown to dramatically exacerbate the erosive impacts of vessel- and wind-generated waves. In contrast, natural shorelines dissipate energy across the sloped profile, when waves encounter a vertical structure, their energy is reflected, further eroding waterward sediments and vegetation (Figure 3).

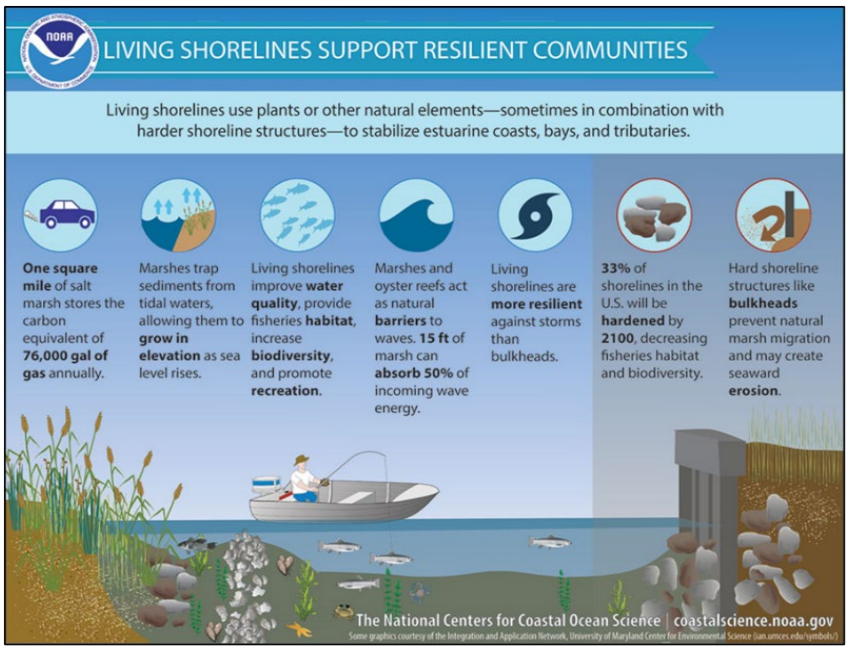


Figure 1. The ecosystem and resilience benefits of living shorelines used for shoreline stabilization. Source: NOAA

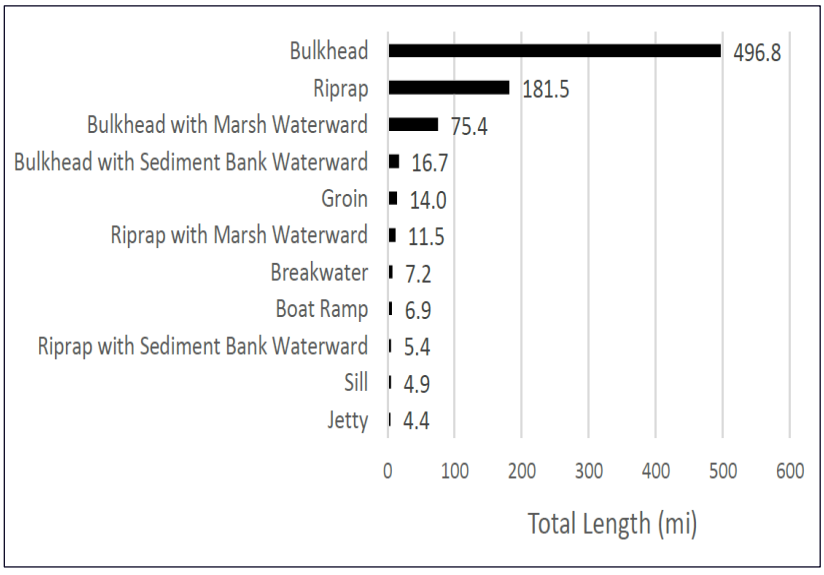


Figure 2. Coastwide extent of shoreline with shoreline structures within North Carolina's 20 coastal counties, based on 2012 aerial imagery[53]. Source: NC CHPP 2021 Amendment[2].

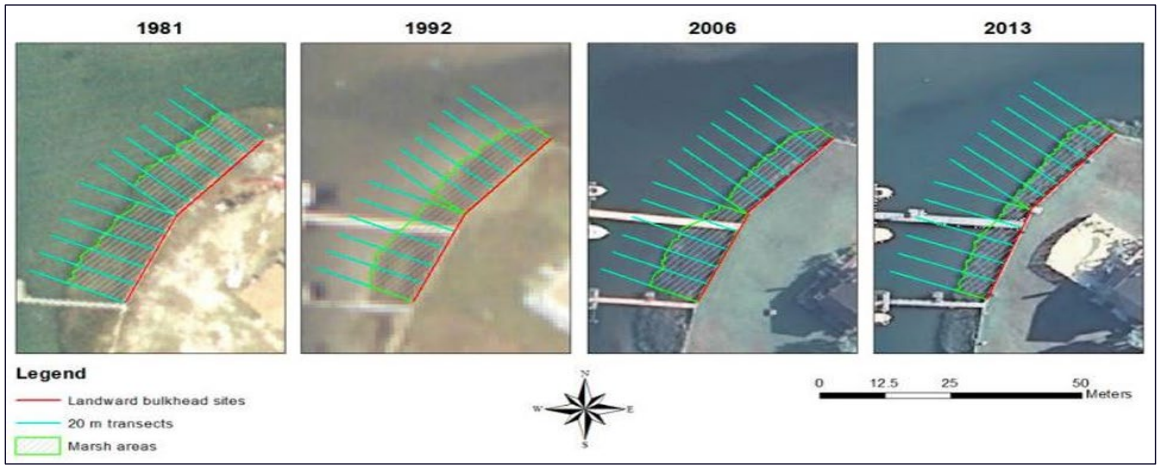


Figure 3. Time series of two bulkhead sites illustrating changes in marsh width, 1981-2013[54]. The red delineates the bulkhead locations, blue delineates 20m transects, and the green areas outline the marsh. Source: NC CHPP 2021 Amendment[2].

Increasing coastal development is expected to increase the demand for shoreline stabilization. More than 48,000 properties valued at $13 billion are predicted to become chronically inundated by 2100 under relatively conservative SLR estimated values that could more than double under more extreme SLR scenarios. Utilizing vertical armoring structures to temporarily maintain the horizontal position of shorelines and protect landward property could dramatically accelerate the loss of waterward marshes through erosive processes, an effect compounded by sea level rise.

1.2.2.2. Stormwater runoff and pollution

Stormwater runoff and pollution pose significant threats to the health and sustainability of salt marshes and surrounding ecosystems (i.e., oyster reefs, SAV beds) in North Carolina, compromising their ecological integrity and the numerous benefits they provide. One of the primary concerns is the increasing influx of stormwater runoff into salt marsh ecosystems. Urbanization and land development often lead to increased impervious surfaces, such as roads and parking lots, which hinder natural water absorption. Consequently, during rain events, stormwater runoff flows more rapidly across these surfaces, accumulating pollutants along the way. When this contaminated runoff reaches salt marshes, it introduces a suite of pollutants, including sediments, nutrients, heavy metals, and chemicals.

The excess nutrients, particularly nitrogen and phosphorus, delivered by stormwater runoff can trigger eutrophication within the salt marshes, leading to the proliferation of algae. Furthermore, stormwater runoff carries sediments that can smother the marsh vegetation and alter sediment composition. The sedimentation process reduces light penetration in the water, inhibiting photosynthesis and impeding the growth of essential marsh plants. Such alterations can result in the loss of plant diversity, affecting the overall resilience of the salt marsh ecosystem. Finally, toxic pollutants carried by stormwater runoff, including oil, heavy metals, and chemicals, pose direct threats to the wildlife inhabiting salt marshes. The toxic substances can accumulate in sediments and water, affecting the health of fish, invertebrates, and bird species that rely on the marsh as a critical habitat for feeding and breeding.

1.2.2.3. Ditching and Draining

Since the early twentieth century, salt marshes along the east coast of the US have been altered in attempt to control mosquito populations. Some of the earliest alteration methods included extensive parallel grid-ditching and impounding[55]. The widespread use of the parallel grid-ditching method has been shown to lead to cascading negative impacts. By ditching the marsh, the natural hydroperiod (i.e., the depth and duration of inundation) is altered. Modifying the hydrology of wetlands can significantly impair or impede many essential functions and

services provided by the ecosystem, including sediment transport and nutrient cycling. Many marshes that have been extensively ditched tend to drain much more rapidly, resulting in decreased water filtration and nutrient retention and prolonged oxidized conditions, negatively affecting organic matter accumulation and soil chemistry. These altered soils can then negatively impact wetland vegetation, becoming less suitable for native plants and more suitable for invasive or exotic species[56].

Over the last 50 years, these alteration methods have been modified to have fewer harmful impacts on the marshes. These newer methods include Open Marsh Water Management (OMWM) and the more recent and holistic approach of Integrated Marsh Management (IMM). However, as sea levels are rising, it is imperative to more fully understand the possible impacts that mosquito ditches and other hydrology alteration methods have or will have on marshes. Marshes are becoming wetter and, with the assistance of the ditches, could drown. Similarly, the drainage ditches utilized in freshwater and agricultural lands could potentially lead to increased levels of saltwater intrusion, thus increasing the rate of habitat transition from freshwater to saltwater species.

1.2.2.4. Boat Wake-Generated Shoreline Erosion

Boating activity and subsequent boat wake, especially in shallow and narrow waters, can cause significant damage and harm to wetlands when mismanaged (Figure 4). The repetitive and forceful impact of boat wakes hitting the shore can lead to physical erosion of the shoreline and the marsh sediment structure, as well as scouring the bottom of the shoreface. The constant battering undermines the stability of the shorelines, gradually wearing away the soil and vegetation that serve as crucial buffers against erosion. Additionally, the disturbance created by boat wake disrupts the natural hydrological balance within salt marshes. These ecosystems depend on a delicate equilibrium between tidal flows, sediment deposition, and plant growth. The turbulence generated by boat wakes can alter sediment distribution and interfere with the marsh's ability to naturally accrete sediments, ultimately affecting its capacity to keep pace with SLR.

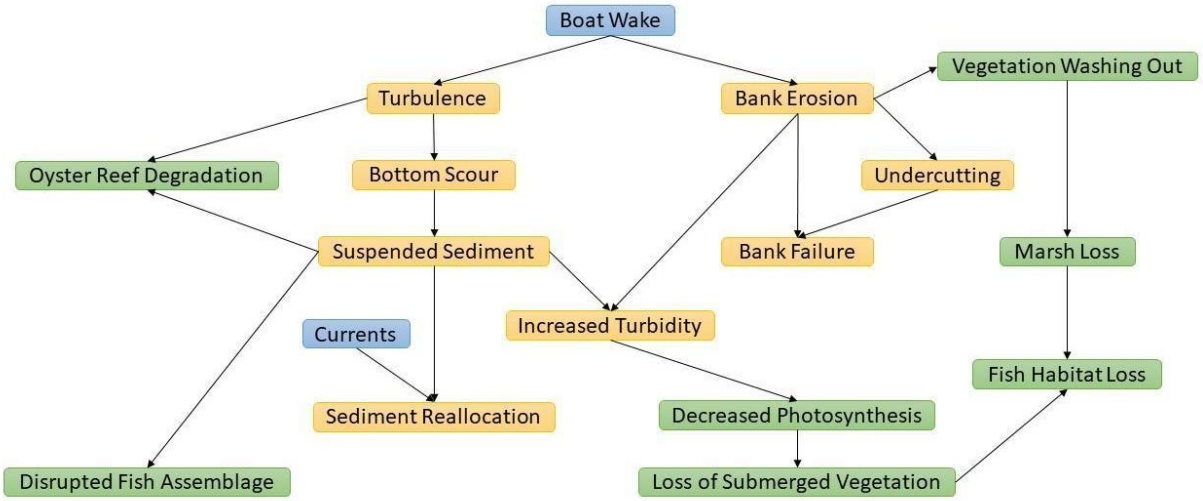


Figure 4. Potential impacts from boat wakes to some different aquatic resources[57]. The blue boxes represent drivers of change, yellow boxes represent changes in ecosystem structures and functions, and green boxes represent impacts on living resources. Adapted from Liddle and Scorgie, 1980[58].

Furthermore, boat wake may contribute to the resuspension of sediments in the water, leading to increased turbidity and a temporary decrease in water clarity. Elevated turbidity levels can impede light penetration, hampering photosynthesis for marsh vegetation. This disruption in plant productivity not only weakens the marsh's structural integrity but also compromises its role as a habitat and breeding ground for various species, including fish and migratory birds. Finally, the forceful boat wakes can physically damage the marsh vegetation and faunal communities directly.

As coastal population continues to rise, so too does the number of boaters within the coastal waters. The damaging effects of boat wake combined with the increased number of boats on the water contribute to the growing need and desire for shoreline armoring, compounding the threats against salt marshes, especially in narrow and shallow coastal waters.

1.2.2.5. Marine Debris

Marine debris, as defined by The Marine Debris Act (33 USC § 1956(3)) as "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes," is a rapidly growing and compounding anthropogenic threat to coastal and oceanic systems worldwide[59]. In 2010 alone, it is estimated that about 5-12.5 million metric tons of plastic waste entered the ocean from nearly 200 different coastal countries[60]. Ranging in size from micrometers (e.g., microplastic fragments, microfibers) to meters (e.g., abandoned or derelict vessels), this debris has been observed from pole to pole across the globe and in almost every perceivable coastal or ocean ecosystem. Pieces of microplastics are even being discovered within organisms, like bivalves and fish, that are consumed by others, including humans. When left in the ecosystem, marine debris negatively impacts the environment, economy, health, and safety of coastal organisms and communities.

Many characteristics and traits that allow salt marshes to provide crucial services, such as sediment trapping and erosion control, also make it very easy to trap marine debris, threatening the health of the surrounding vegetation and organisms. The dense vegetation and complex root systems within wetlands ensnare debris carried in by either the coastal tides or the landward stormwater discharge. Common types of marine debris found in wetlands include microplastics, fishing gear (e.g., fishing nets, fishing lines, crab pots), wooden dock fragments, and abandoned or derelict vessels. When large or heavy debris washes into wetlands, it can become lodged in the soft sediment, where it can remain for several weeks or years. The presence of this large debris can negatively impact the wetland aesthetic, entrap or snag estuarine organisms (including fish, mammals, and birds), and destroy the marsh vegetation. Uhrin and Schellinger[61] conducted a study observing the response of a North Carolina marsh – specifically, the dominant grass *Spartina alterniflora* – to marine debris over time. They observed that after 13 weeks in the marsh, tires and wired crab pots caused the direct destruction of the above-ground grasses and the burial and subsequent suffocation, death, and loss of grass stems. While the smaller pieces of debris pose less of a direct threat to wetland vegetation and cultural values, they are often ingested by key estuarine organisms, such as birds, turtles, fish, and bivalves[62]. The small microplastic fragments have also been shown to alter the carbon and nutrient fluctuations within the water column and sediments, altering biological processes[63].

There are currently many international, federal, and state-wide efforts to address the marine debris issue. In North Carolina, NCCF published the NC Marine Debris Action Plan in January 2020. This plan is complimentary to the Southeast Regional Marine Debris Plan, coordinated by the National Oceanic and Atmospheric Administration (NOAA) in 2019, and provides a strategic plan for the prevention and removal of marine debris throughout coastal North Carolina.

1.2.2.6. Invasive Species

Invasive species can pose a significant and multifaceted threat to North Carolina's salt marshes. These resilient non-native plants and animals outcompete and displace native species, disrupting the fragile balance of the salt marsh ecosystem. The introduction of invasive species, such as *Phragmites australis*, in North Carolina's salt marshes can occur through various pathways, including ballast water discharge from ships, unintentional transport by recreational boaters, or even deliberate release for landscaping purposes. Once established, invasive species can rapidly colonize and dominate marsh landscapes, altering the structure and composition of the habitat. This not only jeopardizes the biodiversity of these vital coastal ecosystems but also undermines their ability to provide critical services, such as water filtration, erosion control, and essential nursery grounds for

various marine species. The introduction of invasive species often results in the loss of native plant diversity, compromising the resilience of salt marshes to environmental stressors, including SLR and climate change. As invasive species continue to encroach upon these valuable habitats, the need for vigilant monitoring for early detection and prompt removal efforts becomes increasingly crucial to safeguard the ecological integrity and functions of salt marsh ecosystems.

1.2.2.7. Climate Change and Sea Level Rise

The effects of climate change arguably represent the greatest threat to the function and persistence of salt marshes today. In many cases, the effects of climate change, such as SLR, increased sea surface temperature, droughts, floods, and heatwaves, will interact synergistically and with non-climate stressors (e.g., coastal development, shoreline armoring, sediment limitation, pollution) to accelerate salt marsh degradation and losses. For example, increased surface water runoff and pollution from development compounded by wetter storm events may increase nutrient delivery to marshes. This may alter salt marsh plants' above- and below-ground biomass ratios and accelerate microbial decomposition of organic matter within soils[52]. Already destabilized by reduced below-ground plant biomass and lower soil organic matter content, marsh edges may be increasingly vulnerable to collapse with rising sea levels and increasing tropical storm intensity. All these individual and compound effects of climate change on salt marshes must be considered and underscore the need to take action to mitigate climate change. However, among the impacts of a changing climate, SLR and its interactive effects with shoreline hardening, development, and sediment limitation are likely to have the most significant impact on the future abundance and distribution of salt marshes along the North Carolina coast[37]. Salt marshes are periodically inundated by the tides. As sea levels rise and storms become more frequent and wetter, however, these periods of inundation will become more and more prolonged until the marsh is forced to react or drown.

Saltwater Intrusion

Rising sea levels presents a different concern. As the sea levels rise, saltwater becomes more and more prevalent inland, an event known as saltwater intrusion. Saltwater intrusion (SWI) refers to the process in which saltwater infiltrates freshwater, surface water, groundwater, or terrestrial systems due to various environmental (i.e., storm surge, subsidence, rebound) and anthropogenic factors (i.e., ditching, land drainage, land use changes)[64]. This surplus of saltwater in these systems can significantly damage and eventually alter their composition, ecological function, and services offered.

Significant increases in salinity can be damaging to salt-intolerant species. Should the exposure to high-salinity conditions persist long enough, the entire community can shift permanently. If the salt-intolerant species cannot survive in the new conditions, they are outcompeted by the more salt-tolerant species, shifting the dynamics of the ecosystem. This shift in ecosystem can be beneficial to salt marshes, as it helps to facilitate their migration and the creation of new marsh. However, this can be concerning to landowners and land managers depending on terrestrial or freshwater species or those dependent on dry or low salinity environments. One prevalent example of this habitat transition along the coast of North Carolina is the emergence of ghost forests (Figure 5). Ghost forests are stretches of dead trees found in what used to be freshwater forests. As saltwater infiltrates the system, the trees cannot survive, and the freshwater forests are transitioning to tidal swamps. These are particularly evident on the Albemarle-Pamlico peninsula[65]. In the Alligator River National Wildlife Refuge, for example, 11% of the forested land transitioned to ghost forest between 1985 and 2019[66]. In addition to the freshwater forests, increases in SWI from SLR also pose threats to current agricultural and other working lands (Figure 6). As more saltwater seeps into the soil, the environment will become less suitable for many crops, hindering growth and production.

Figure 5. Creation of ghost forests along the Virginia Eastern Shore from saltwater intrusion. Photo: Arielle Bader (@abaderphoto).

Figure 6. Saltwater intrusion into agricultural fields in NC. Photo: Dr. Matthew Ricker/NCSU.

1.2.3. Salt Marsh Response to Sea Level Rise

Salt marshes have two primary responses to the threat of SLR and extended periods of inundation – vertical accretion or horizontal migration (Figure 7). Several factors will determine a marsh's response to a threat. Salt marshes vary in many natural attributes (e.g., plant community, hydrodynamics, elevation, and sediment composition and availability) and are exposed to different anthropogenic influences (e.g., coastal development, dredging, and stormwater runoff)[67,68,69]. The combination of these factors affects the way marshes react to different threats. It is essential for effective marsh conservation and planning to recognize how marshes can or cannot respond[70]. If sediment accumulation within the marsh cannot keep pace with the rising seas, these vertically challenged wetlands will drown. Similarly, horizontally challenged marshes facing wave-induced marsh edge erosion on one side and coastal development barriers on the other cannot migrate inland and will drown[71]. Many of the recommended actions detailed within this plan focus on developing and implementing various strategies to help salt marsh accrete vertically, migrate horizontally, or do both.

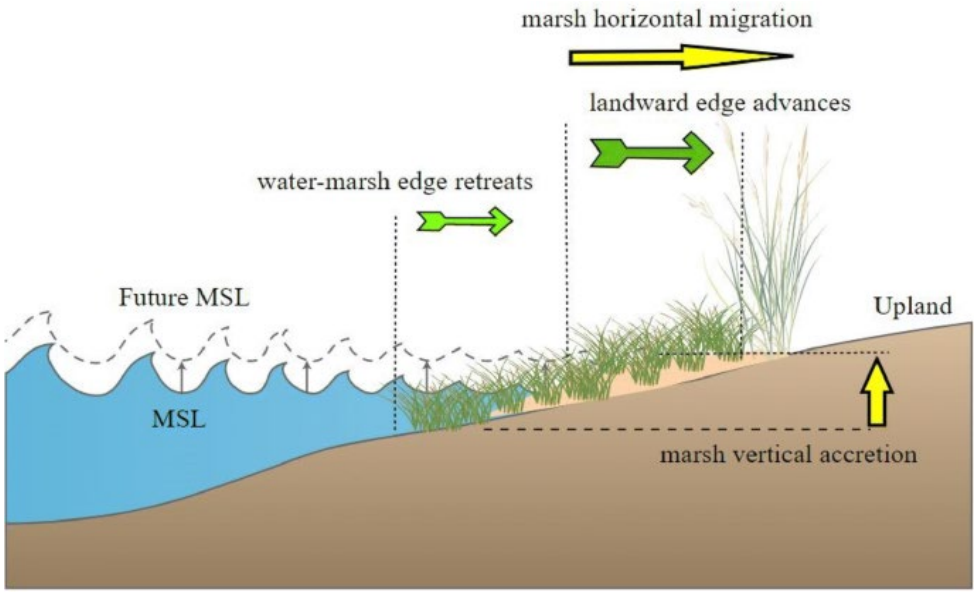


Figure 7. Diagram of vertical and horizontal marsh responses to sea-level rise[70].

1.2.3.1. Vertical marsh accretion

For salt marshes to persist in place, they must rise vertically at a rate equal to or greater than that of rising sea levels. Vertical marsh accretion occurs with the accumulation of organic matter (i.e., root material) and sedimentation. Both sources of material are important. One study[72] demonstrated that marshes have a theoretical maximum vertical accretion rate of 5 mm per year. This rate is based on the highest sediment loading rates of combined inputs of organic and inorganic materials. According to a different study[73], this maximum accretion rate is equivalent to the current rate of SLR of the southeastern Chesapeake Bay, which was approximately 5.1 mm per year with an acceleration of about 0.16 mm each year.

Long term analysis of SLR and salt marsh accretion, however, indicates that North Carolina marshes are particularly vulnerable to the negative effects of SLR[74]. Marshes cannot indefinitely survive a higher rate of SLR in the absence of a significant source of inorganic sediment. The suspended sediment supply throughout coastal North Carolina waters is relatively lower. Analysis of Surface Elevation Table (SET) data between the year 2004-2018 indicates that local sea levels in North Carolina were rising approximately 7.5 mm/yr. Marshes must be able to accrue sediment at an equal or faster rate than that of the rising sea levels to avoid total inundation and drowning. If they fail to keep pace vertically, they must retreat horizontally and migrate inland.

1.2.3.2. Horizontal marsh migration

Salt marshes have a second mechanism for responding to SLR, which involves migrating landward. As sea levels rise, saltwater floods inland habitats, infiltrating the soil. The increased soil salinity makes the low-lying forests and agricultural lands less habitable for saltwater-intolerant species. Halophytic marsh vegetation eventually replaces terrestrial and freshwater plants as the marsh-upland boundary moves landward. However, this process is influenced by many environmental and anthropogenic factors, including topography, hardened structures, shoreline armoring, and drainage features. Land use, however, is among the most impactful, as marsh migration along its natural path is impeded in areas with hardscapes like roads or urban development. When this occurs, the marsh erodes at the waterward extent and remains stationary at the landward extent. The marsh becomes trapped between rising sea levels and impediments to inland migration, known as coastal squeeze (Figure 8). In North Carolina, there are buffer rules and regulations in place that aim to restrict development from encroaching upon the water. However, as sea levels continue to rise, the shoreline that is typically above water will inevitably be impacted. This will reduce buffer zones, posing challenges for stakeholders and communities along the coast[70]. Eventually, as SLR and SWI become severe enough (3.3ft SLR by 2100), salt marsh will be much less

hindered by development and will migrate beyond these barriers. For the timeline of this plan (1.5ft SLR by 2050), however, the focus is to prevent and remove such barriers to allow for clear migration pathways.

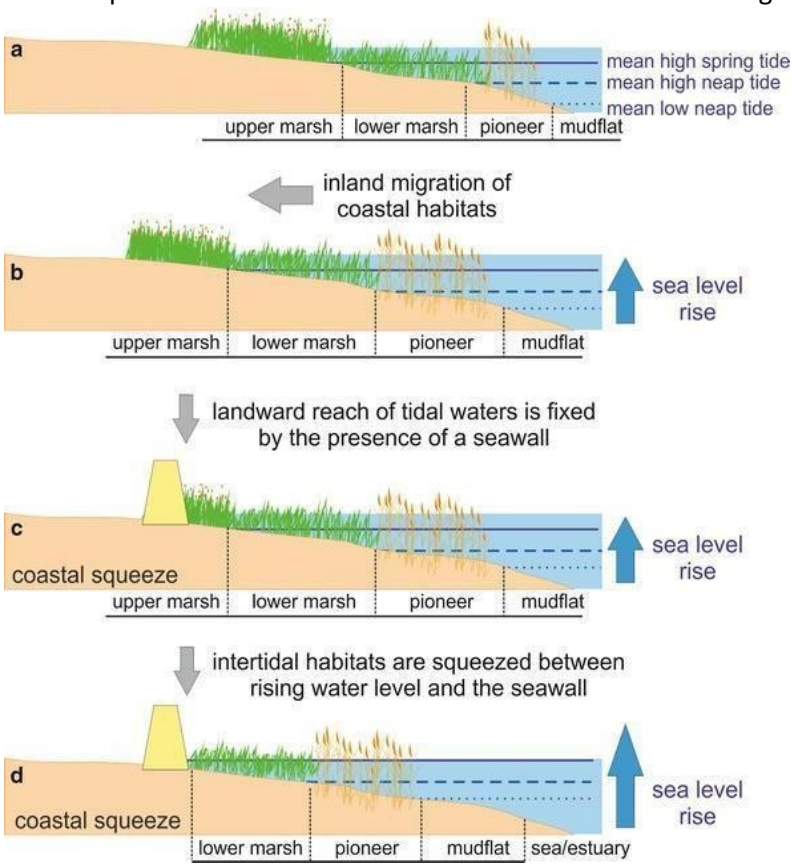


Figure 8. The elevation in relation to the tidal range is one of the key factors determining the type of intertidal habitat that may develop in a particular location **(a)**. Natural habitats tend to migrate inland as a response to rising sea levels **(b)**. As a result of this migration the intertidal area may expand or reduce depending, for example, on the coastal topography. Hard engineering structures will invariably fix the landward limit of intertidal areas **(c)**, which will be reduced in extent as sea levels rise and more land becomes permanently inundated **(d)**. The loss of coastal habitats due to rising sea levels in front of artificially fixed shorelines is known as coastal squeeze. Source: Esteves, 2016[75].

2. Current and Projected Status of North Carolina Salt Marsh

Presently, North Carolina has about 220,000 acres of salt marsh along its coast (Figures 9a and 10a-c). These marshes are found lining the mainland side of estuaries, as isolated marsh complexes within the open water estuarine system, and behind the state's barrier islands. By 2050, a projected 1.5-foot rise in sea level would dramatically alter the landscape of salt marshes across the North Carolina coast. Utilizing data derived from Warnell, et al., (2022)[37] and ArcGIS Pro geospatial analysis software, salt marsh gains and losses throughout North Carolina are projected in this plan based on the intermediate sea level rise scenario. Assuming a sustained level of development, no efforts to slow or impede salt marsh encroachment into agricultural or forested uplands, and no major ecological or geological changes, the salt marsh acreage throughout the state could nearly double to almost 400,000 acres (Figures 9b and 10d-f). However, the projected distribution of salt marsh and, thus, its local and regional ecosystem service provisioning will not be evenly divided along the coast and is projected to shift dramatically. For more detailed images of the projection analysis, see Appendices B and C.

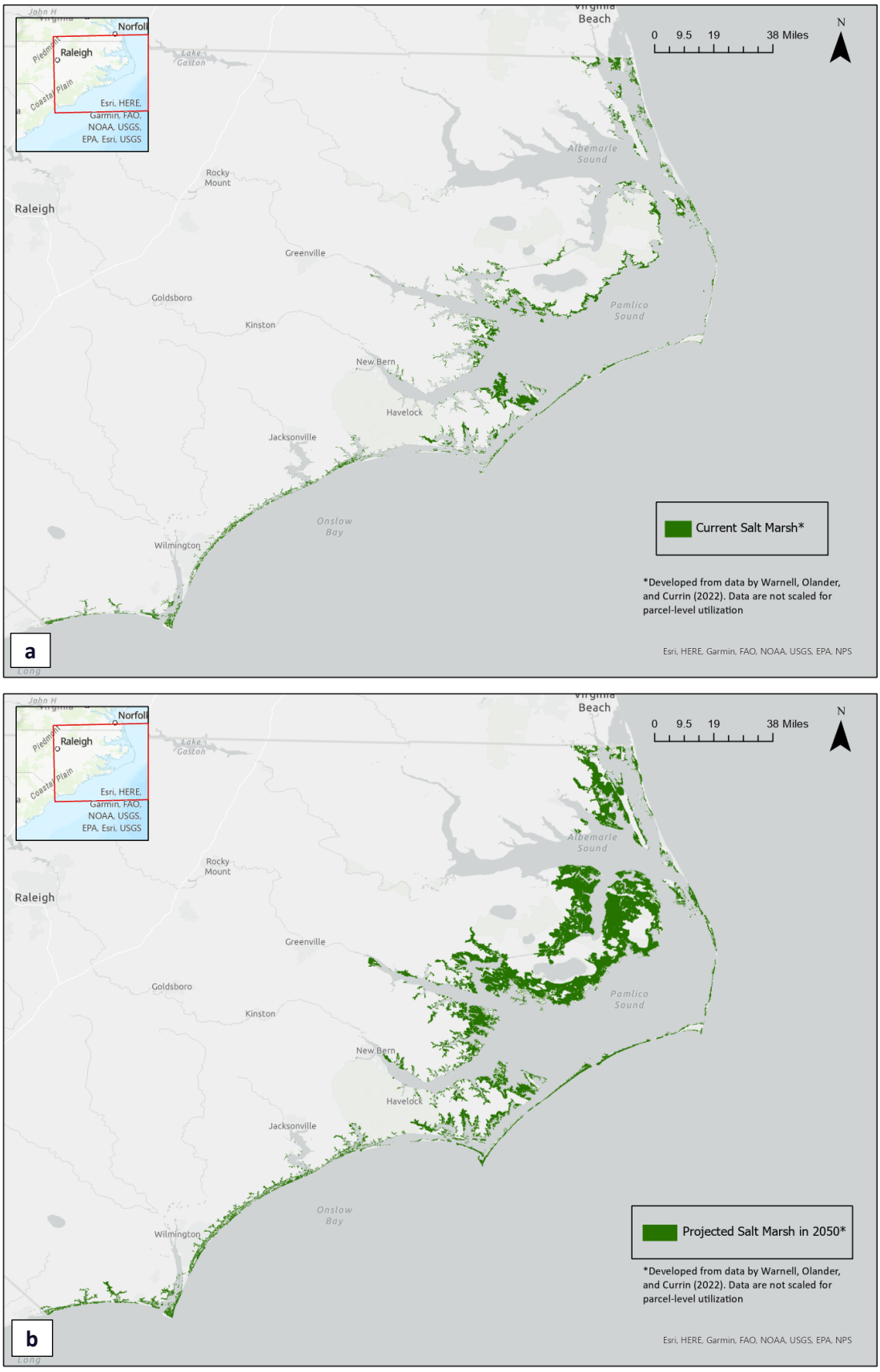


Figure 9. Current **(a)** and 2050 projections **(b)** of salt marsh coastwide throughout North Carolina under an intermediate (1.5ft) sea level rise scenario, assuming no major geological, ecological, or developmental changes.

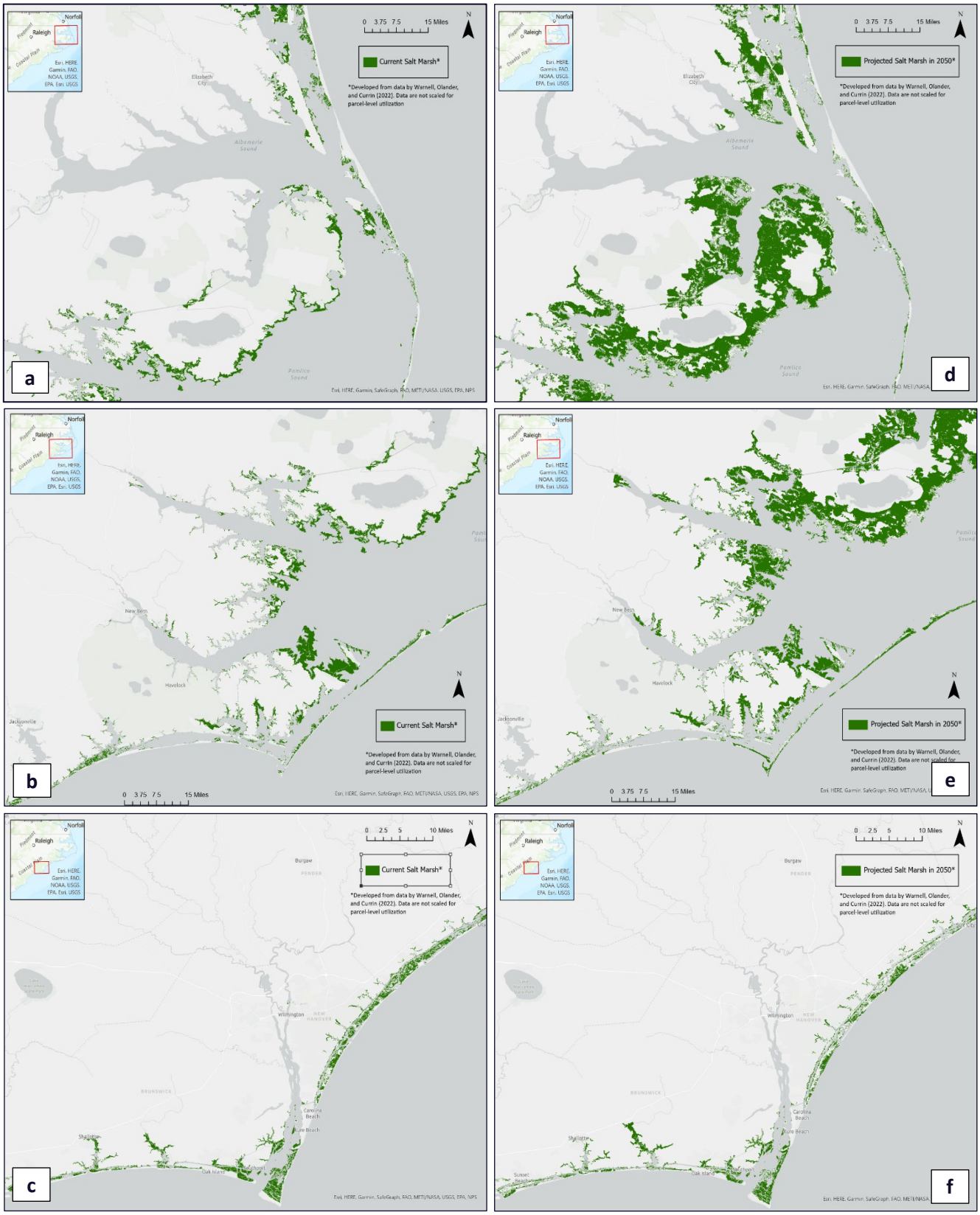


Figure 10. Current **(a, b, c)** and 2050 projections **(d, e, f)** of salt marsh by region throughout North Carolina under an intermediate (1.5ft) sea level rise scenario, assuming no major geological, ecological, or developmental changes.

Owing to the geology of North Carolina's coastal plain, the availability of potential marsh migration space differs dramatically between the northern and southern portions of the coast. Roughly bisected by the Suffolk Scarp (Figures 11 and 12), the lower elevation of land in the northern portion of the coast affords appreciably more potential marsh migration space than do the higher elevations of the southern coast. Indeed, under intermediate SLR projections for 2050 (+0.46m relative to 2010), North Carolina is projected to lose approximately 92,000 acres of existing salt marsh and gain more than 270,000 acres of new marsh. Yet, most net gains in salt marsh acreage are projected to occur within mainland watersheds in the northern and central coast, while the majority of losses are observed along the barrier islands and southern coast.

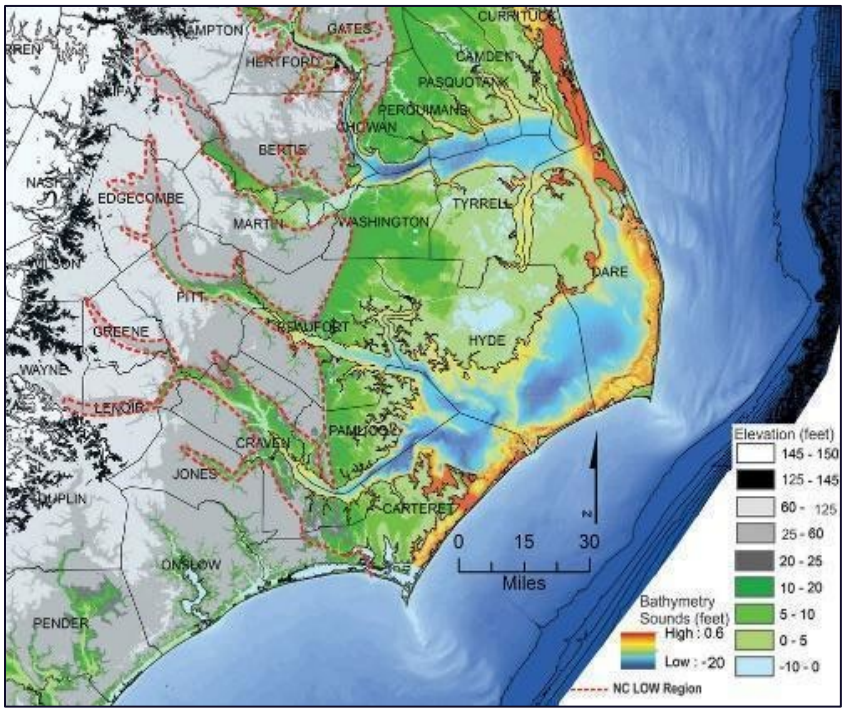


Figure 11. The elevation of eastern North Carolina showing the location of the Suffolk Scarp, along the red dashed line. Map from NC Land of Water[76].

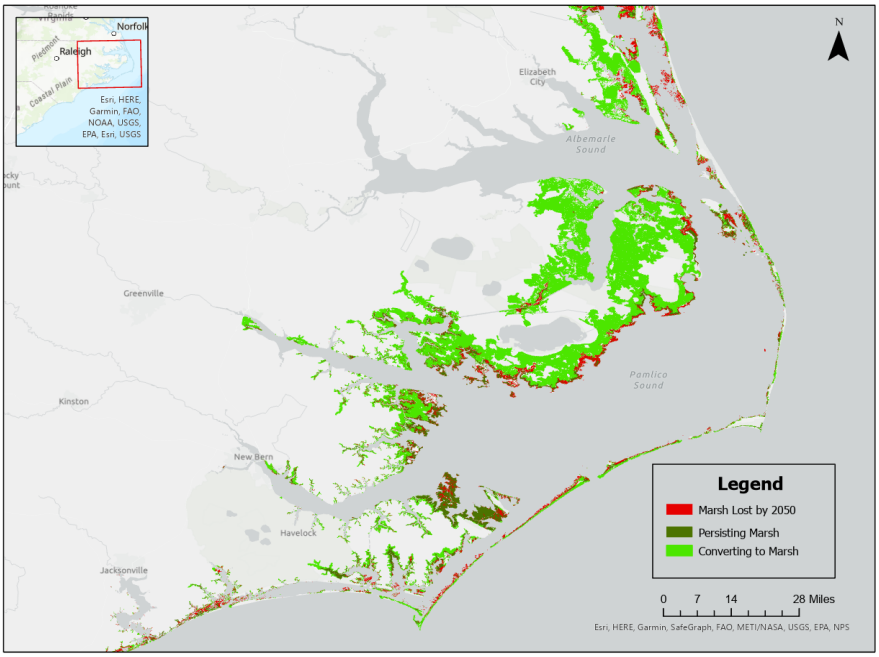


Figure 12. Salt marsh projections for 2050 within the Suffolk Scarp region.

The vast disparity of salt marsh projections across the coast justifies the need to divide the coastline into smaller fragments (Figure 13a). The region is divided into small watershed units based on the US Geological Survey's 10-digit hydrologic unit code (HUC-10) watershed units directly connecting to estuarine surface waters in which salt marsh is currently present or is projected to exist by 2050 under intermediate SLR predictions of about 1.5 feet. (Figure 13b). These HUC-10s were then trimmed and amended into the plan's 38 conservation planning units (CPUs) based on jurisdictional and ecological needs to provide more specialized recommendations for salt marsh throughout the state (Figure 13c). The 2050 marsh projection data were then clipped to the individual CPUs, and that allowed total acreage of marsh gained or lost to be calculated within each CPU between now and 2050 (Appendix D). Figure 13d illustrates the magnitude of the gain or loss within each CPU throughout the state.

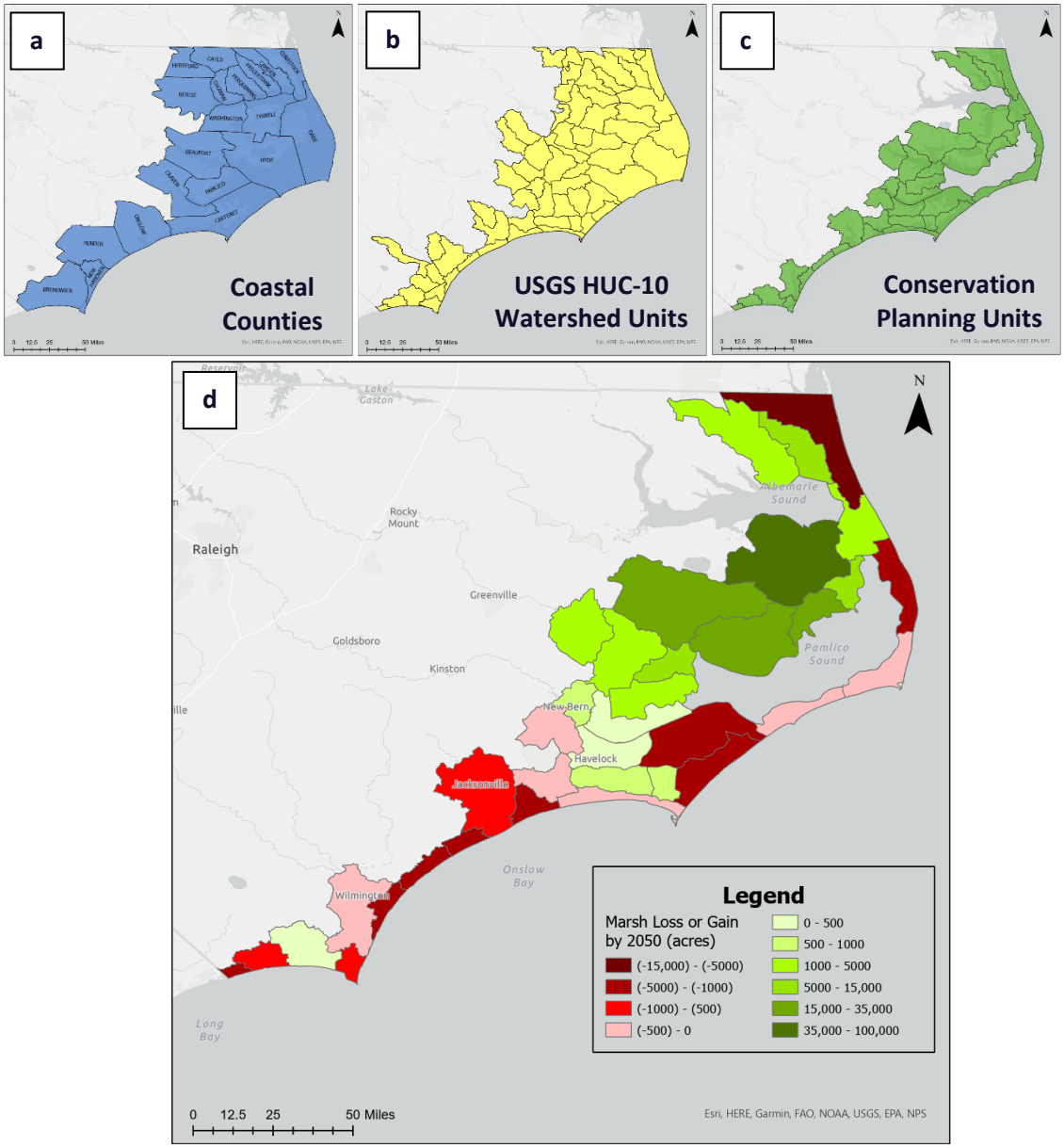


Figure 13. The coast of North Carolina **(a)** divided into smaller segments based on the US Geological Survey's 10-digit hydrologic unit code (HUC-10) watershed units connected to estuarine surface waters **(b)** in which salt marsh is currently present or is projected to exist by 2050 under intermediate sea level rise (SLR) predictions of approximately 1.5 feet and amended into conservation planning units (CPU) based on jurisdictional and ecological needs **(c)**. Projected net salt marsh acreage change between present and 2050 under an intermediate SLR scenario of 0.46m relative to 2010 **(d)** with the color fill of each CPU corresponding with projected net change, barring no major developmental or geological changes.

2.1. Implications of Future Projections

The prospective loss of salt marshes in North Carolina carries multifaceted implications, impacting both the environment and human communities. With a 1.5ft rise in sea level, the coast of North Carolina will change dramatically (Figure 14). Much of the low-lying lands in the central and northern regions of the coast will become increasingly inundated until permanently submerged. The barrier islands will become even more subjected to overwash and the creation of new inlets. Consequently, as the seas rise and these occurrences of overwash and new inlet formations increase, saltwater intrusion will be at an all-time high, leading to landward salt marsh migration and habitat transitions. Regions along the coast with heavy shoreline armoring will be subjected to more destruction and loss of vital coastal habitats and vegetation. These unique coastal ecosystems provide a range of invaluable ecological services, and their decline could result in far-reaching consequences, such as increased erosion and storm damage, decreased carbon sequestration potential, and the collapse of crucial nursery and breeding grounds for ecologically and commercial significant wetlands species.

While these outlooks are projected to 2050, several areas are currently experiencing the negative effects of rising sea levels and climate change. There is already evidence of marsh loss, increased saltwater intrusion, and marsh migration occurring throughout the Coastal Plain of North Carolina. This reinforces the immediate and urgent need for organized action. By enhancing existing marsh and bolstering its capacity for sediment accrual, the marsh can keep pace with SLR vertically. Simultaneously, facilitating marsh migration and establishing clear, protected migration corridors will allow the marsh to retreat horizontally, preserving the coastal protection and other benefits it provides.

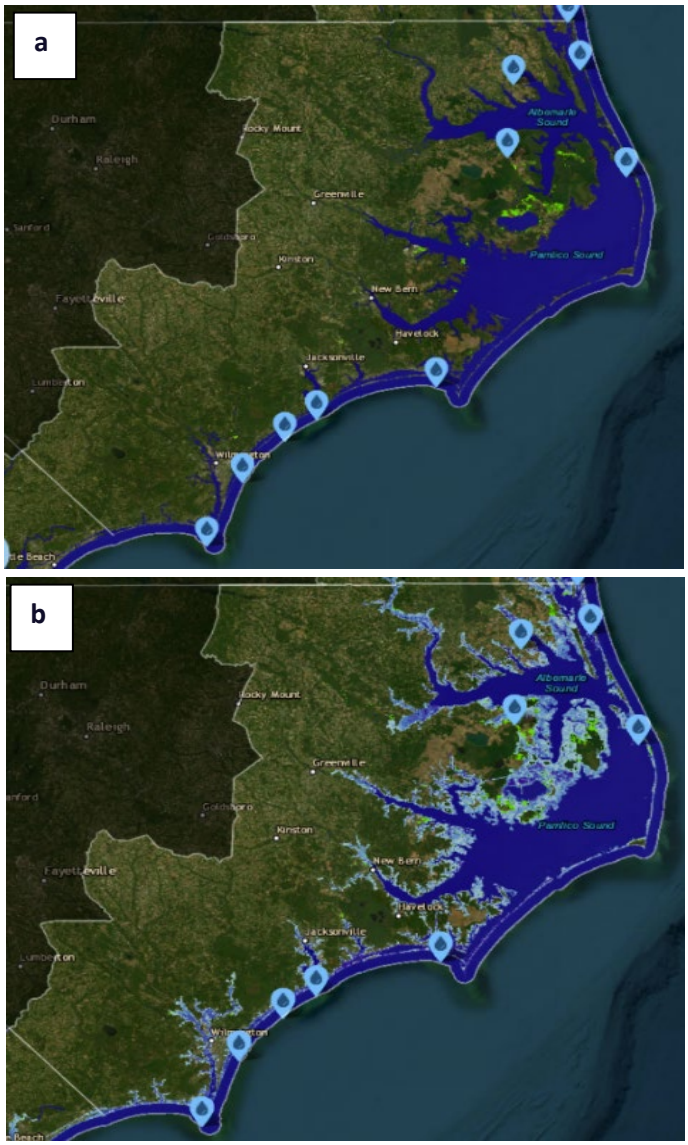


Figure 14. North Carolina coastline with the **(a)** current mean high-water line and with **(b)** 2ft of sea level rise. Source: NOAA[77].

Across the US, especially along the coast of the southeastern US, SLR is expected to have disproportionate impacts on socially vulnerable communities[78,79,80], with residents in rural coastal communities, such as North Carolina's Albemarle-Pamlico Peninsula, especially exposed to the impacts of SLR[81] (Figure 15). Handwerger et al. 2021[82] examined the differential impacts of SLR on minority and economically disadvantaged communities in the Carolinas, finding that "as SLR progresses throughout the century, impacts grow increasingly disproportionate by as much as two-fold for low-income alone and low-income Black coastal communities at 2- and 4-ft of SLR… [and that] 2-ft of SLR is expected to increase 700% for low-lying flooding in the most economically disadvantaged, Black communities compared to economically disadvantaged, white communities." Supporting these findings, participants in a mapping exercise during the August 2022 workshop (Appendix A) emphasized the forecasted impacts of marsh migration on the historically Black community of North River in Carteret County.

Given the ways that government actions supporting coastal protection, navigation, and development resulted in displacement and exacerbation of existing inequalities facing Black communities across the coastal southeastern US[83], addressing the vulnerabilities and needs specific to these communities will be imperative as SLR accelerates. Recent literature has documented significant risks to minority and low-income communities that arise from "colorblind" resilience and adaptation efforts and policies that don't take into consideration the histories and challenges faced by those communities[79,80], suggesting that such adaptation and hazard mitigation efforts can further redistribute vulnerability toward those already-vulnerable groups[84] and exacerbate existing racial wealth inequality[85]. As SLR drives marsh migration and loss in North Carolina's socially vulnerable communities, particularly minority and low-income communities, it will be crucial for government agencies and NGOs to prioritize proactively collaborating with and supporting these communities in planning and funding efforts that enhance adaptation to rising seas and migrating marshes.

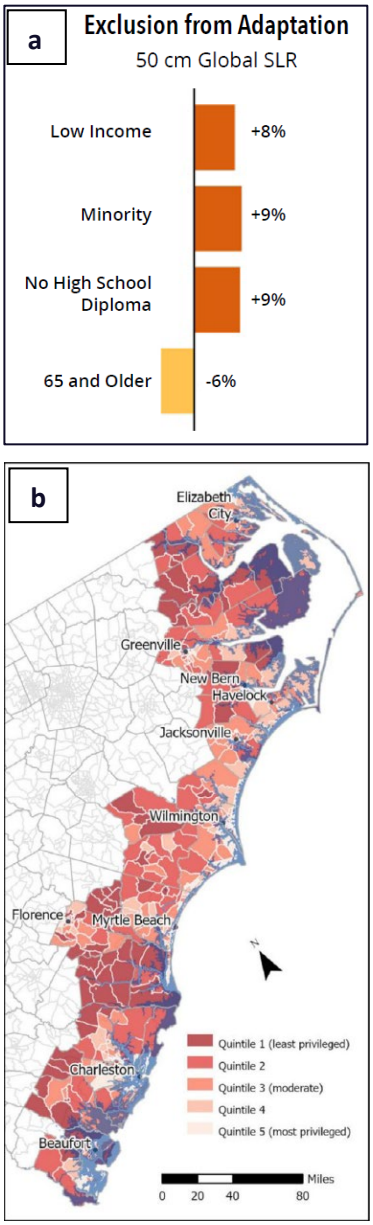


Figure 15. (a) Increased likelihood of being excluded from adaptation to coastal inundation by social vulnerability factor[86]. **(b)** Spatial vulnerability for least privileged vs. most privileged quintiles of racial segregation and income disparities at 2 feet of SLR[82].

3. Recommended Actions

Based on the projected trends for North Carolina's salt marshes detailed in the previous section, and given the imminent pressures from the increasing threats, there are a number of actions that must be taken promptly to protect, restore, and enhance this vital coastal habitat. These threats are often interconnected, and addressing them requires comprehensive and integrated management strategies, involving government agencies, conservation organizations, researchers, and local communities. Conservation efforts that consider the cumulative impacts of these threats are crucial for the long-term health and resilience of salt marsh in North Carolina and elsewhere. This section describes the various components necessary to accomplish just that (please note: strategies, objectives, and actions are not listed in any priority ranking).

In coordination with the SASMI Plan, there are three guiding strategies of the NC SMAP necessary to achieve the overarching goal. These strategies detail approaches to conserve, restore, and facilitate the migration of salt marshes based on the needs and projections of North Carolina. Each strategy has multiple objectives and necessary recommended actions for implementation. These recommended actions are the product of multiple collaborative workshops and discussions with local stakeholders and experts (Appendix A). Where appropriate and feasible, the objectives and actions are aligned and coordinated with those of the SASMI Plan. Finally, for each action, the outputs and intended results of its successful completion have been identified.

GOAL: *Protect, restore, and facilitate the migration of salt marshes in North Carolina to minimize loss of function, benefits, and acreage through 2050 and beyond.*

3.1. Strategy 1. Advance Salt Marsh Conservation and Restoration.

Conserving and restoring existing salt marshes in North Carolina in the face of intensifying SLR, storms, and erosion is essential to maintaining the acreage and ecological functions of these valuable coastal ecosystems and the services they provide. If marshes continue to degrade or drown, coastal communities will become more vulnerable to storm surge and erosion, wetland-dependent species will lose habitat, essential nursey areas, or breeding grounds, and the ability to help address climate change impacts through greenhouse gas sequestration will be jeopardized. This section details numerous objectives and actions recommended to restore lost or degraded marsh, enhance existing marsh, and protect current and future marsh from further damages and threats. In general, these recommendations aim to assist sediment accrual for more efficient vertical accretion, reduce impacts of pollution and runoff through effective stormwater management, enhance existing or degraded marsh through the implementation and development of both proven and new restoration techniques, and increase public awareness and engagement to reduce pollution, encourage responsible land use, and help safeguard North Carolina's coastal habitats. This aligns with the SASMI Plan Strategy 1: Protect and restore the health and functions of existing salt marshes.

Objective A. Protect salt marshes from new and existing stressors to minimize impacts from landward activities (Table 2).

Table 2. Strategy 1-Objective A. Protect salt marshes from new and existing stressors to minimize impacts from landward activities.

Action 1.A.1. Prevent outfalls to marshes	**Description:** Review existing water quality and sedimentation development standards to examine the effectiveness of current standards, need for additional standards, and potential enforcement challenges.	**Outputs:**	Regulatory guidance
		Results:	Marsh protection from stormwater runoff damage
Action 1.A.2. Educate and adjust stormwater policies to protect salt marsh	**Description:** Encourage local municipalities and state agencies to adopt stormwater controls that protect marshes on individual and community waterfront properties, including helping to strengthen and enforce the DEQ Coastal Stormwater Program.	**Outputs:**	Educational stakeholder meetings
		Results:	Adopted or adjusted stormwater management policies; better protection for marshes on private lands
Action 1.A.3. Maintain and promote adequate and larger setbacks and vegetated buffers	**Description:** Work with local communities, municipalities, and state lawmakers to maintain and promote adequate setbacks while building support for larger setbacks (>30') for development from marshes to allow for more protective riparian waterfront areas and marsh migration corridors.	**Outputs:**	Outreach and educational materials; relevant stakeholder meetings; more vegetated buffers; adjustments to local and state development standards; demonstration projects
		Results:	Adaptable management of development that is safer for both infrastructure and the salt marsh to account for sea level rise and more intense storms
Action 1.A.4. Prevent filling near marshes	**Description:** Maintain contiguous freshwater wetlands adjacent to marshes to maintain overall hydrology, storm protection, and future marsh migration areas through restoration and strategic land acquisition.	**Outputs:**	Outreach and educational materials; cost-share to help maintain natural vegetative buffers; site development standards
		Results:	Natural habitat conversion; room for marsh migration; storm buffers better protecting waterfront development
Action 1.A.5. Prevent and manage invasive species	**Description:** Prevent and manage invasive species from encroaching on marsh areas by focusing on early detection, prompt removal, and using inventories and maps to prioritize problem areas where marshes are being degraded by invasive species.	**Outputs:**	Preventative efforts; consistent monitoring and managing; prioritized itinerary; maps and GIS data; pilot early detection management program
		Results:	Halted spread of invasive species within marshes; information to support decision-making; early removal of invasive species

Objective B. Promote and advance restoration, protection, and conservation of salt marshes to support salt marsh and broader estuary health (Table 3).

Table 3. Strategy 1-Objective B. Promote and advance restoration, protection, and conservation of salt marshes to support salt marsh and broader estuary health.

Action 1.B.1. Continue and advance salt marsh restoration and protection	**Description:** Continue and expand the restoration and protection of degraded or vulnerable salt marshes while exploring and advancing new measures for restoration and protection.	**Outputs:**	Restored and enhanced connecting marsh complexes
		Results:	Healthier and more resilient salt marshes; reconnect fragmented marshes; enhance long-term stability; advancement of marsh restoration and protection measures
Action 1.B.2. Continue and expand salt marsh conservation	**Description:** Continue and expand salt marsh conservation to protect existing marshes through conservation projects, funding opportunities, land acquisition, and easements.	**Outputs:**	Varying marsh conservation projects along the coast
		Results:	Protection of existing salt marshes for continued habitat value and ecosystem services
Action 1.B.3. Engage in management planning processes	**Description:** Engage in relevant land and water resource management planning processes to incorporate indicators of salt marsh and estuarine ecosystem health as metrics for success.	**Outputs:**	Updated management strategies
		Results:	Land management strategies that include indicators of salt marsh and ecosystem health as metrics for success.

Objective C. Facilitate and expand the use of living shorelines to protect and restore salt marsh edges (Table 4).

Table 4. Strategy 1-Objective C. Facilitate and expand the use of living shorelines to protect and restore salt marsh edges.

Action 1.C.1. Continue use of living shorelines	**Description:** Continue and expand the use of living shorelines as the preferred shoreline stabilization method to protect and restore salt marsh, especially in lieu of bulk heads where appropriate.	**Outputs:**	Varying living shoreline projects along the coast; more plantings
		Results:	More abundant and more successful living shoreline projects; protected infrastructure and salt marsh
Action 1.C.2. Expand funding for cost-share program	**Description:** Maintain and enhance federal, state, and local funding for cost-share programs to encourage the use of living shorelines and better establish private market demand.	**Outputs:**	Applications and requests for funding
		Results:	Increased funds to offset costs of living shorelines as financial incentives
Action 1.C.3. Continue and advance education and outreach	**Description:** Maintain consistent education and outreach about the merits of living shorelines with federal and state agencies, landowners, landscapers, engineers, marine contractors, real estate agents, local governments, and any other stakeholders that can influence how waterfront properties are managed and protected.	**Outputs:**	Educational and outreach materials; consistent meetings and sharing of information
		Results:	Increased awareness about nature-based alternatives to shoreline stabilization and increased demand for living shorelines
Action 1.C.4. Expand capacity of contractors to grow their own plants	**Description:** Expand the capacity of contractors to provide needed plants for living shorelines by demonstrating the utility of a “donor marsh” and by working with nurseries to encourage them to grow more plants each year.	**Outputs:**	Reports; successful plant nurseries and donor marshes
		Results:	Continual, sustainable, ready source of plants for living shoreline projects

Action 1.C.5. Conduct research	**Description:** Conduct research on predetermined topics and knowledge gaps to help with project designs and to ensure environmentally compatible projects, including studies into the long-term interaction between living shorelines and SAV, water quality, and fish utilization and the best designs for fish passages.	**Outputs:**	Information; data; reports
		Results:	Increased knowledge and understanding about living shorelines, adaptive design, and impact on surrounding environment

Objective D. Facilitate and advance salt marsh research and assessment to protect and restore existing salt marshes and improve salt marsh function (Table 5).

Table 5. Strategy 1-Objective D. Facilitate and advance salt marsh research and assessment to protect and restore existing salt marshes and improve salt marsh function.

Action 1.D.1. Support the development of a Beneficial Use of Dredge Spoils Plan	**Description:** Support and collaborate with partnering agencies to develop a Beneficial Use Plan for North Carolina for all areas where routine dredging is conducted by federal, state, local, and private entities. Seek to achieve the US Army Corps of Engineers' national goal of 70% beneficial use of dredge spoils.	**Outputs:**	Statewide Beneficial Use Plan for NC
		Results:	More methods and options for coastal habitat restoration
Action 1.D.2. Identify compromised marsh complexes	**Description:** Inventory and map threatened, degraded, or eroded marsh complexes based on acreage, ecological, and protective functions.	**Outputs:**	Maps and GIS data
		Results:	Information to support decision-making
Action 1.D.3. Prioritize inventoried sites and identify potential restoration techniques	**Description:** Continue restoration efforts by prioritizing identified sites based on federal, state, and/or local criteria and identifying potential restoration techniques for each prioritized site.	**Outputs:**	Prioritized list of sites with possible restoration techniques
		Results:	Cost-effective use of funds and resources based on priority
Action 1.D.4. Identify and develop additional funding mechanisms	**Description:** Work with partnering agencies from all levels of government to identify and develop additional funding mechanisms that can support prioritized projects on both public and private lands.	**Outputs:**	Funding mechanisms
		Results:	More specific opportunities to fund marsh restoration on different levels

3.2. Strategy 2. Facilitate Salt Marsh Migration.

The strategy of facilitating salt marsh migration is rooted in the recognition of the imminent challenges posed by SLR. As climate change is causing rising sea levels and an increase in more frequent and stronger storms, freshwater and terrestrial systems are becoming more and more inundated by saltwater. This persistent saltwater intrusion eventually leads to a shift in habitats from dry land to more freshwater and saltwater wetlands, especially in areas of lower elevation and minimal shoreline armoring. Much of this salt marsh migration has been occurring for centuries but will become more rapid along the central and northern coast of North Carolina, impacting many communities, farms, and forested areas.

Given the concern that some landowners and managers may have and given that saltwater intrusion resulting from SLR is exceedingly difficult and expensive to prevent, the feasibility of stopping marsh migration is very low over the long run. Therefore, the need in some locations is to collaborate with communities and help them to protect the status quo for as long as practical, while also planning for orderly and strategic transitions as both

groundwater and sea levels rise. By providing resources and fostering resilience in coastal communities, we seek to address the implications of this habitat shift and, in turn, contribute to the well-being of these communities for as long as possible. This strategic adaptation requires cooperation among all stakeholders, recognizing the shared interest in building a sustainable and thriving future for coastal regions.

This section details numerous objectives and actions recommended to overcome the various obstacles (i.e., roads, coastal development, funding) and collaborate with community members and stakeholders. Taking these steps and working toward these objectives will help facilitate successful habitat transition and salt marsh migration. This aligns with the SASMI Plan Strategy 2 Conserve marsh migration corridors and remove or retrofit barriers to ensure salt marshes can shift as sea levels rise.

Objective A. Conserve migration corridors through land acquisitions and easements, securing necessary funding and resources, and updating planning and management practices (Table 6).

Table 6. Strategy 2-Objective A. Conserve migration corridors through land acquisitions and easements, securing necessary funding and resources, and updating planning and management practices.

Action 2.A.1. Utilize easements to avoid urbanization in migration corridors	**Description:** Obtain funding for the implementation of projects that focus agricultural farmland easements within marsh migration areas to avoid urbanization of those zones.	**Outputs:**	Easement contracts
		Results:	Increased protected land for marsh migration
Action 2.A.2. Focus NRCS programs within migration corridors	**Description:** Concentrate Natural Resources Conservation Service's (NRCS) wetland protection and enhancement cost-share programs within salt marsh migration areas.	**Outputs:**	Identification and maps; stakeholder engagement; documents and reports
		Results:	Increased protected land for marsh migration
Action 2.A.3. Secure easements under the USDA federal farm bill conservation programs	**Description:** Use USDA federal farm bill conservation programs to secure conservation easements and undertake hydrology restoration on lands that are becoming marginally productive due to saltwater encroachment and flooding.	**Outputs:**	Easements; restoration projects
		Results:	Increased protected land for marsh migration
Action 2.A.4. Collaborate with land management agencies	**Description:** Work with state and federal land management agencies to ensure that their land management strategies are conducive to marsh migration needs and work to establish uniform policies.	**Outputs:**	Updated and promoted management strategies and policies
		Results:	Land management that is beneficial to future marsh; consistent land management for marsh migration
Action 2.A.5. Obtain funding to work with federal and state agencies	**Description:** Obtain resilience funding to work with NC DOT, DoD, USDA, DCM, and other state and federal agencies to ensure that infrastructure planning and investments align with future marsh migration needs.	**Outputs:**	Applications and requests for funding
		Results:	Increased opportunities for marsh-friendly infrastructure planning

Objective B. Encourage the inclusion of marsh migration as a priority in planning and investments in infrastructure, wetland restoration, and working lands to facilitate migration and improve management practices (Table 7).

Table 7. Strategy 2-Objective B. Encourage the inclusion of marsh migration as a priority in planning and investments in infrastructure, wetland restoration, and working lands to facilitate migration and improve management practices.

Action 2.B.1. Utilize local government regulations to better manage new development within marsh migration pathways	**Description:** Work with local governments to better manage for new development in low-lying areas near salt marshes to avoid blocking potential migration pathways.	**Outputs:**	Regulation; management strategies
		Results:	Increased protected land for marsh migration
Action 2.B.2. Develop guidance and incorporate marsh migration into state policies	**Description:** Coordinate with state agencies to provide guidance for including marsh migration projections and needs in state policies including the Uniform Floodplain Management Policy and Flood Resiliency Blueprint.	**Outputs:**	Updated Policy and Blueprint
		Results:	More comprehensive decision-making and flood policy to include marsh migration
Action 2.B.3. Advocate for the adjustment of grant funding scoring criteria	**Description:** Advocate for the adjustment of the grant funding scoring criteria used by public and private funders to incentivize the use of conservation areas to allow for marsh migration.	**Outputs:**	Adjusted scoring criteria
		Results:	Increased protected land for marsh migration
Action 2.B.4. Include nature-based strategies, sea level rise, and marsh migration within flood mitigation projects	**Description:** Work with state agencies to ensure that nature-based strategies that consider sea level rise and marsh migration needs are fully reflected in flood mitigation projects undertaken along the coast.	**Outputs:**	Updated strategies
		Results:	More effective and sustainable coastal flood mitigation
Action 2.B.5. Encourage state legislation and Executive Orders	**Description:** Encourage and help implement state legislation and/or Executive Orders that guide government investments in state and community infrastructure that reflect projected marsh migration patterns and needs.	**Outputs:**	New and updated legislation
		Results:	Infrastructure development that is forward-thinking, environmentally conscious, and adaptive to marsh migration
Action 2.B.6. Develop guidance to incorporate marsh migration into public infrastructure investments	**Description:** Develop guidance for partners of the Eastern NC Sentinel Landscape (ENCSL) to ensure public investments in infrastructure and military operations align with marsh migration needs and priorities.	**Outputs:**	Guidance document
		Results:	Align human activities like infrastructure and military ops. with the changing needs of marsh migration, fostering a more sustainable and eco-conscious approach within the ENCSL
Action 2.B.7. Develop a decision-support tool for tidal stream crossings	**Description:** Develop a decision-support tool for enlarging roadway tidal stream crossings to promote marsh migration.	**Outputs:**	Decision-support tool
		Results:	More informed decision-making and planning
Action 2.B.8. Address hydrologic barriers to marsh migration	**Description:** Identify, prioritize, and address hydrologic barriers to marsh migration through removal or retrofitting.	**Outputs:**	Prioritized lists of locations and strategies
		Results:	More effective and efficient marsh migration

Objective C. Advance research and assessment of salt marsh migration areas (Table 8).

Table 8. Strategy 2-Objective C. Advance research and assessment of salt marsh migration areas.

Action 2.C.1. Update and refine existing marsh migration projection maps	**Description:** Update and refine existing marsh migration projection maps to account for the influence of existing drainage systems, patterns in rainfall, etc. to enhance prioritization efforts.	**Outputs:**	Maps; GIS data
		Results:	More informed planning and decision-making; readily available data for prioritization and decision-making
Action 2.C.2. Inventory and prioritize migration areas	**Description:** Inventory and prioritize migration areas based on specific strategies (i.e., acquisition, conservation based on inevitable natural processes and existing land uses, most vulnerable to sea level rise, management for marsh movement on conservation lands purchased with public funds).	**Outputs:**	Prioritized lists
		Results:	More informed planning and decision-making; readily available data for prioritization and decision-making
Action 2.C.3. Identify prior converted croplands within migration corridors	**Description:** Identify for conservation the federally designated "prior converted cropland" located within known marsh migration corridors.	**Outputs:**	Map; GIS data
		Results:	Increased protected land for marsh migration
Action 2.C.4. Update hydrology restoration designs for sea level rise based on research	**Description:** Support research that projects how the geology and hydrology of existing shorelines, barrier islands, and coastal plain wetlands will change with sea level rise and work with NRCS to ensure that hydrology restoration designs account for this.	**Outputs:**	Research projects, reports, data; adjusted design processes
		Results:	Adaptive planning; updated and more comprehensive understanding of coastal dynamics

3.3. Strategy 3: Incorporate Cross-Cutting Approaches.

In addition to the objectives and actions outlined for Strategy 1 and 2 mentioned above, there are several crucial cross-cutting approaches this strategy focuses on that are essential for advancing ongoing efforts to conserve and restore both existing and future salt marshes. First, it is vital to always leverage the latest advancements in science and technology to inform management and policy decisions. Given the continuous development of new technologies, monitoring methods, and implementation strategies, it is paramount that our management practices, policies, and regulations remain abreast of these innovations to optimize the use of time, resources, and efforts. Further, securing funding to implement the strategies is critical to the successful implementation of the plan to protect and restore salt marshes and conserve marsh migration corridors. The actions detailed below are recommended to ensure that our conservation and restoration endeavors remain effective and adaptive. This aligns with the SASMI Plan's Crosscutting Approaches.

Objective A. Conduct research, support monitoring efforts, and pursue funding opportunities (Table 9).

Table 9. Strategy 3-Objective A. Conduct research, support monitoring efforts, and pursue funding opportunities.

Action 3.A.1. Research	**Description:** Develop and publicize yearly research priorities related to marsh restoration, conservation, and migration, and circulate to researchers and their funders.	**Outputs:**	Itinerary of areas of research needs/interests
		Results:	Comprehensive understanding of knowledge gaps and needs
Action 3.A.2. Refine and publish marsh projection data	**Description:** Continue to refine and publish SLR-driven marsh loss and migration projection data across multiple platforms, including ArcGIS Online. Add projection data layer to such projects and tools as the NC OneMap and the NOAA Digital Coast.	**Outputs:**	GIS data and layers
		Results:	More comprehensive knowledge for public and private sectors for planning, research, etc.
Action 3.A.3. Monitor water quality	**Description:** Develop ambient water quality and water level monitoring stations throughout coastal water bodies.	**Outputs:**	Monitoring stations; data
		Results:	Comprehensive understanding of coastal water quality
Action 3.A.4. Support long-term mapping and monitoring efforts	**Description:** Support a coordinated federal and state mapping effort to utilize existing information, identify and address gaps, and seek funding necessary to monitor salt marshes over time to determine status and trends and overall ecosystem health.	**Outputs:**	Maps; GIS; reports
		Results:	Up-to-date and readily available data for prioritization and decision-making; comprehensive understanding of marsh trends and projections; adjust management strategies
Action 3.A.5. Pursue funding opportunities	**Description:** Identify and pursue funding to support salt marsh restoration, conservation, protection, and migration efforts and research.	**Outputs:**	Applications; requests; list of possible funding sources
		Results:	Increased funding for salt marsh conservation, restoration, and protection

Photo: NCCF

Secondly, building upon existing policy, laws and programs at the local, state and federal levels and pursuing new policies to plan and implement initiatives to conserve and restore salt marshes while accommodating migration is critical. Salt marshes exist within a dynamic coastal environment and a complex legal, regulatory and policy framework. Coordination and collaboration with state, federal, and local partners present an opportunity to gain a comprehensive understanding of the existing framework, as well as identify and pursue opportunities to strengthen and build upon it in ways that bring improved results for salt marshes and stakeholders.

Objective B. Encourage policy and management adjustment (Table 10).

Table 10. Strategy 3-Objective B. Encourage policy and management adjustment.

Action 3.B.1. Conduct regulatory gap analysis	**Description:** Collaborate with state and federal agencies to conduct a gap analysis of existing state, regional, and federal laws, policies, and programs relevant to the protection and restoration of salt marshes, shoreline buffer restrictions, living shorelines and other nature-based solutions, and the conservation of marsh migration corridors.	**Outputs:**	Regulatory framework summary; regulatory guidance; adaptive management strategies
		Results:	Identify policies and regulations that promote environmentally beneficial coastal development; installation of more nature-based solutions; protected essential public infrastructure
Action 3.B.2. Identify alternative permitting strategies	**Description:** Collaborate with state and federal agencies to identify alternative permitting strategies, provide regulatory guidance, and adjust management strategies to ensure that the most effective and environmentally beneficial project designs are consistently selected as part of permit processes for living shorelines and other nature-based solutions.	**Outputs:**	Updated permitting processes, policies, and guidance; adaptive management strategies; streamlined permitting process
		Results:	Updated policies and regulations that promote environmentally beneficial coastal development; installation of more nature-based solutions; efficient permitting process that encourages using living shorelines when they are the best environmental alternative; programmatic review of large-scale projects
Action 3.B.3. Develop and update decision-support tools for salt marsh protection and restoration methods	**Description:** Collaborate with state and federal agencies, academia, and other organizations to develop and maintain an online resource as a guide to implementation of the regulatory process that can be used by agencies and permit applicants to determine the most cost-effective, environmentally beneficial, and readily permissible protection and/or restoration methods for individual project sites (i.e., beneficial use of sediments, marsh grass plantings, oyster reef creation or enhancement, living shorelines).	**Outputs:**	Reference document; online portal; decision-making tools; guidance documents; update existing tools/guidance documents (i.e., NOAA, DCM); updated permitting processes, policies, and guidance; better coordination between stakeholders
		Results:	Improved and informed decision-making; efficient permitting roadmap
Action 3.B.4. Inform decision-makers	**Description:** Ensure appropriate decision-makers are kept informed of important information, progress, and needs.	**Outputs:**	Reports; meetings
		Results:	Improved and more informed decision-making

Thirdly, there must be a sustained effort to engage stakeholders and target audiences through comprehensive education and outreach programs. This engagement is fundamental for building a strong foundation of support, understanding, and cooperation among all parties involved, ranging from local communities and landowners to government entities and NGOs. By fostering a culture of informed participation and dialogue, we can ensure that conservation and restoration initiatives are not only more broadly supported but also enriched by diverse perspectives and localized knowledge. The following actions aim to feed this continuous loop of engagement and feedback that will facilitate the creation and implementation of solutions that are both ecologically sound and socially equitable, thereby enhancing the effectiveness and sustainability of these efforts.

Objective C. Communicate, educate, and engage with target audiences and communities (Table 11).

Table 11. Strategy 3-Objective C: Communicate, educate, and engage with target audiences and communities.

Action 3.C.1. Raise public awareness	**Description:** Raise public and decision-maker awareness about the importance of salt marshes and their role in coastal resilience to foster community support for conservation efforts.	**Outputs:**	Educational materials; outreach events
		Results:	More informed public to support and demand marsh restoration and conservation efforts
Action 3.C.2. Identify target audiences	**Description:** Identify target audiences to educate and engage (i.e., waterfront property owners, working landowners, government decision-makers, landscapers, real estate professionals, engineers, developers, contractors).	**Outputs:**	Targeted educational and outreach materials
		Results:	Individualized education for more effective communication
Action 3.C.3. Encourage public support	**Description:** Encourage public support for policies and projects that promote marsh conservation through regular media stories, etc.	**Outputs:**	Educational materials; outreach events
		Results:	Increased dissemination of knowledge and understanding
Action 3.C.4. Educate local communities through a Coastal Leadership Institute	**Description:** Educate local communities (i.e., schools, homeowners associations, government planners, soil and water conservation districts) about the importance of salt marsh migration and restoration and its role in coastal resilience through a planned Coastal Leadership Institute.	**Outputs:**	Educational materials; outreach events
		Results:	More informed communities to support marsh conservation efforts
Action 3.C.5. Assign local points of contact for landowners	**Description:** Implement well-advertised and easily accessible "points of contact" for landowners to obtain assistance for managing their land and salt marsh migration, and support the development of peer-led public forums and learning opportunities.	**Outputs:**	Personnel; educational materials; forums
		Results:	Supported and informed communities, leading to improved land management practices that are compatible with salt marsh migration
Action 3.C.6. Engage with and support underserved communities	**Description:** Engage with underserved communities, particularly those at risk due to rising sea levels and consequent marsh loss or migration, to understand their needs, and collaborate with organizations to proactively develop and deliver resources to those communities.	**Outputs:**	Educational materials; informational meetings; outreach events; funding
		Results:	Strong relationships and communities that are more prepared and resilient to respond to the challenges posed by sea level rise and marsh loss or migration.

4. Plan Implementation

Approach

Given the urgency of this situation, it is imperative to act in an organized, well-thought-out, and structured manner. To achieve efficient and effective implementation of the NC SMAP, it is important to collaborate with partners to 1) incorporate actions into existing efforts and programs, and 2) identify new pathways to implement actions. This includes identifying, partnering on, and facilitating complementary and synergistic projects for salt marshes that involve and benefit federal, state, and local governments, military, land trusts, private landowners, and/or vulnerable and marginalized community members. There are many efforts already underway in North Carolina to advance the strategies and actions in the NC SMAP. Collaboration is key to ensuring the NC SMAP is additive and complementary to these existing efforts by leveraging resources and expertise to achieve common goals and objectives.

Framework

While action at the regional and national scale holds significance, the majority of the SASMI Plan implementation will take place at the state and local levels. The success of the SASMI Plan relies on the establishment of teams within each SASMI state (State Implementation Team – SIT) tasked with the development and implementation of state specific plans that include priority actions tailored to the assortment of state- and local-level challenges and opportunities. This entails delineating specific projects, pathways, and involved stakeholders for addressing the designated projects/actions, along with identifying funding sources, establishing timelines, and defining metrics of success. The North Carolina Coastal Federation is charged with leading the North Carolina SIT (NC SIT). The NC SIT is charged with facilitating the implementation of the NC SMAP and SASMI Plan through collaboration with partners and stakeholders, while engaging target audiences, supporting ongoing efforts, and sharing information regularly. The Salt Marsh Steering Committee (SMSC) was formed to function as the NC SIT, bolstering and building on North Carolina's long history of salt marsh protection and restoration efforts. The SMSC members are individuals from several key organizations that represent a wide spectrum of sectoral and geographic interests and subject matter expertise. The composition of the SMSC was judiciously selected to include 20-25 actively engaged professionals with expertise relevant to the goals and objectives of the NC SMAP and SASMI Plan, a group with the collective knowledge and experience to guide effective project implementation.

In recognition of the fact that understanding how communities are being impacted by changes to salt marsh extent and function requires robust engagement with diverse stakeholders, a Stakeholder Advisory Committee (SAC) was established. The SAC comprises various federal-, state-, and local- government agency representatives, academics, community members, special interest groups, and NGOs. With a diverse and inclusive membership of over 100 stakeholders, its purpose is to provide high level guidance and feedback on the implementation of the NC SMAP and SASMI Plan, serving in an advisory compacity to the SMSC and ensuring the stakeholder and decision-maker engagement, guidance, and support that is critical to successfully carrying out actions prioritized in the NC SMAP. The SMSC utilizes various workgroups to provide critical information on specific action items, focus areas, and priorities set by the SMSC. Where priority areas align with existing committees and workgroups affiliated with external efforts or organizations, the SMSC has worked to support and integrate with those groups rather than creating SMSC-specific workgroups in order to minimize redundancy. Existing committees already incorporated under the SMSC include the North Carolina Living Shorelines Steering Committee and the North Carolina Coastal Carbon Collaborative. As implementation of the NC SMAP and SASMI Plan progresses, other workgroups may be identified to further streamline efficiency and effectiveness.

Together, these teams help with the development of a prioritized and comprehensive list of potential projects throughout North Carolina, pathways for implementation, stakeholders to involve, and funding sources to

implement actions identified within the NC SMAP. A non-exhaustive list of existing efforts, programs, and tools have been identified by the SMSC as having synergies (Appendix E). Using this information to build upon, a strategic implementation plan is developed each year from the collaborative efforts of the SMSC, SAC, and workgroups to identify priority locations, key partners, necessary courses of action, specific goals, clear metrics of success for accomplishing the plan objectives, and track progress (Appendix F). The SMSC, SAC, and workgroups meet regularly to provide updates, discuss collaboration needs, and assign next steps toward the implementation of the recommended actions. The groups also continue to collaborate with SASMI leadership and coalition members to further implement relevant actions outlined in the SASMI Plan. After five years, the NC SMAP will be revaluated, updated, and re-released to ensure that the recommended actions and guidance are always following the best available science and accurately fulfilling the needs for coastal North Carolina.

This effort began as a regional effort across the South Atlantic states through the work of SASMI. Salt marshes are not bound to state lines, and any threats to their health or work to protect and restore their acreage and function will transcend those lines. The work must start at the state and local level, with regional resources, support, and objectives. As such, the SMSC works closely with SASMI and regional partners to continually identify new and future efforts within North Carolina and beyond. The broader SASMI Partnership Council supports each SIT in efforts to secure resources for implementation, address policy, capacity, or other priority actions, as well as to facilitate coordination with regional-level efforts. Through these collaborative and concerted efforts, we can strive to preserve and enhance all that salt marshes have to offer North Carolina and beyond for decades to come.

Photo: NCCF

5. References

1. US Environmental Protection Agency (EPA). (2023). What is a Wetland? US EPA. Available from: https://www.epa.gov/wetlands/what-wetland.
2. North Carolina Department of Environmental Quality (NC DEQ). (2021). North Carolina Coastal Habitat Protection Plan 2021 Amendment. Department of Environmental Quality, Raleigh, NC. 266 p.
3. Fish and Wildlife Service (FWS). (2020). National Wetland Inventory. U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, DC.
4. Mitsch, W. J., Bernal, B., & Hernandez, M. E. (2015). Ecosystem Services of Wetlands. International Journal of Biodiversity Science, Ecosystem Services, and Management, 11(1), 1–4. https://doi.org/10.1080/21513732.2015.1006250
5. NC DEQ (2023). Current Rate Schedules. Division of Mitigation Services. Available from: https://www.deq.nc.gov/about/divisions/mitigation-services/customers/current-rate-schedules.
6. Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis. Washington, DC: Island Press. ISBN 1-59726-040-1.
7. Hudson, R., Kenworthy, J. & Best, M. (eds) (2021). Saltmarsh Restoration Handbook: UK & Ireland. Environment Agency, Bristol, UK.
8. Mitsch, W.J., & Gosselink, J.G. (2015). Wetlands. (5th ed.) Hoboken, NJ:John Wiley & Sons, Inc.
9. Fretwell, J.D. (1996). National water summary on wetland resources. U.S. Government Printing Office.
10. Poulter, B., Feldman, R.L., Brinson, M.M., Horton, B.P., Orbach, M.K., Pearsall, S.H., Reyes, E., Riggs, S.R., & Whitehead, J.C. (2009). Sea-level rise research and dialogue in North Carolina: creating windows for policy change. Ocean and Coastal Management 52(3-4):147-153.
11. North Carolina Division of Marine Fisheries. (2020). North Carolina Division of Marine Fisheries License and Statistics Section annual report. North Carolina Department of Environmental Quality. Division of Marine Fisheries. Morehead City, NC. 454 p.
12. Purcell A.D., Khanal, P.N., Straka, T.J., & Willis, D.B. (2020). Valuing ecosystem services of coastal marshes and wetlands. Clemson Cooperative Extension, Land-Grant Press by Clemson Extension. LGP 1032. https://doi.org/10.34068/report4.
13. Bratman, G.N., et al. (2019). Nature and mental health: An ecosystem service perspective.Sci. Adv.5,eaax0903.DOI:10.1126/sciadv.aax0903.
14. Willis, C. (2015). The contribution of cultural ecosystem services to understanding the tourism–nature–wellbeing nexus, Journal of Outdoor Recreation and Tourism, 10,38–43.
15. Harrison, J., Pickle, A., Vegh, T., & Virdin, J. (2017). North Carolina's ocean economy: a first assessment and transitioning to a blue economy. NC Sea Grant. UNC-SG-17-02. 26 p.
16. David, M. (2022). Where do License Dollars Go? NC Wildlife Resources Commission.
17. Verschuuren, B. (2016). Religious and Spiritual Aspects of Wetland Management. 10.1007/978-94-007-6172-8_242-2.
18. Shepard, C.C., Crain, C.M., & Beck, M.W. (2011). The protective role of coastal marshes: a systematic review and meta-analysis. PloS One 6(11):e27374.
19. Francalanci, S., Bendoni, M., Rinaldi, M., & Solari, L. (2013). Ecomorphodynamic evolution of salt marshes: experimental observations of bank retreat processes. Geomorphology 195(2013):53–65.
20. Cowart, L., Walsh, J., & Corbett, D.R. (2010). Analyzing estuarine shoreline change: A case study of Cedar Island, North Carolina. Journal of Coastal Research 26(5):817-830.
21. Silinski, A., Schoutens, K., Puijalon, S., Schoelynck, J., Luyckx, D., Troch, P., Meire, P., & Temmerman, S. (2018). Coping with waves: plasticity in tidal marsh plants as self-adapting coastal ecosystem engineers. Limnology and Oceanography 63(2):799815.
22. Currin, C.A., Davis, J., & Malhotra, A. (2017). Response of salt marshes to wave energy provides guidance for successful living shoreline implementation. Living Shorelines: the science and management of nature-based coastal protection. CRC Press, Taylor & Francis Group.
23. Hein, C.J., Fenster, M.S., Gedan, K.B., Tabar, J.R., Hein, E.A., & DeMunda, T. (2021). Leveraging the Interdependencies Between Barrier Islands and Backbarrier Saltmarshes to Enhance Resilience to Sea-Level Rise. Front. Mar. Sci. 8:721904. Doi:10.3389/fmars.2021.721904
24. Center for Coastal Resources Management, Virginia Institute of Marine Science. (2014). Living Shoreline Implementation: Challenges and Solutions. Rivers & Coast, Summer 2014 issue. V.9, no.2. Virginia Institute of Marine Science, College of William and Mary. http://dx.doi.org/doi:10.21220/m2-2d2k-a602.
25. Costanza, R., Pérez-Maqueo, O., Martinez, M.L., Sutton, P., Anderson, S.J., & Mulder, K. (2008). The value of coastal wetlands for hurricane protection. Ambio 37(4):241-48.
26. Narayan, S., Beck, M., Wilson, P., Thomas, C., Guerrero, A., Shepard, C., Reguero, B., Franco, G., Carter Ingram, J., & Trespalacios, D. (2017). The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA. Scientific Reports, 7(9463).
27. Sun, F., & Carson, R.T. (2020). Coastal Wetlands Reduce Property Damage during Tropical Cyclones. Proceedings of the National Academy of Sciences of the United States of America 117(11):5719-5725.
28. Perillo, G, E. Wolanski, D.R. Cahoon, and C.S. Hopkinson. 2018. Coastal wetlands: an integrated ecosystem approach. Elsevier. Perillo, G., Wolanski, E., Cahoon, D.R., & Hopkinson, C.S. (2018). Coastal wetlands: an integrated ecosystem approach. Elsevier.
29. Drake, D.C., Peterson, B.J., Galvan, K.A., Deegan, L.A., Hopkinson, C., Johnson, J.M., Koop-Jakobsen, K., Lemay, L.E., & Picard, C. (2009). Salt marsh ecosystem biogeochemical responses to nutrient enrichment: a paired 15N tracer study. Ecology 90(9):25352546.
30. Trainer, V.L., Davidson, K., Wakita, K., Berdalet, E., Suddleson, M., & Myre, G. (2020). GlobalHAB: Evaluating, reducing and mitigating the cost of harmful algal blooms: a compendium of case studies.
31. Duarte, C.M. (2017). Reviews and syntheses: hidden forests, the role of vegetated coastal habitats in the ocean carbon budget. Biogeosciences, 14(2):301-310 https://repository.kaust.edu.sa/handle/10754/622845.
32. Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Björk, M., Duarte, C.M., Lovelock, C.E., Schlesinger, W.H., & Silliman, B.R. (2011). A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9(10):552-560.
33. Macreadie, P.I., Allen, K., Kelaher, B.P., Ralph, P.J., & Skilbeck, C.G. (2012). Paleoreconstruction of estuarine sediments reveal human-induced weakening of coastal carbon sinks. Global Change Biology 18(3):891-901.
34. Nahlik, A.M., & Fennessy, M.S. (2016). Carbon storage in US Wetlands. Nature Communications 7(1):1-9.
35. Duarte, C.M., Losada, I.J., Hendriks, I.E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change 3(11):961–68.
36. Holmquist, J.R., Windham-Myers, L., Bliss, N., Crooks, S., Morris, J.T., Megonigal, J.P., et al. (2018). Accuracy and Precision of Tidal Wetland Soil Carbon Mapping in the Conterminous United States. Sci Rep. 8: 9478. Pmid:29930337.

37. Warnell, K., Olander, L., and Currin, C. (2022). Sea level rise drives carbon and habitat loss in the U.S. mid-Atlantic coastal zone. PLOS Clim 1(6): e0000044. https://doi.org/10.1371/journal.pclm.0000044.
38. Warnell, K., & Olander, L. (2020). Data from: Coastal protection and blue carbon mapping for six mid-Atlantic states. Duke Research Data Repository. https://doi.org/10.7924/r4pg1qw8p.
39. US EPA. (2021). U.S. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2019. Report No.: EPA 430-R-21-005.
40. Howard, J., Sutton-Grier, A., Herr, D., Kleypas, J., Landis, E., Mcleod, E., Pidgeon, E., & Simpson, S. (2017). Clarifying the role of coastal and marine systems in climate mitigation. Frontiers in Ecology and the Environment 15(1):42-50.
41. Chmura, G.L. (2013). What do we need to assess the sustainability of the tidal salt marsh carbon sink? Ocean Coast Manag. 83: 25–31.
42. Mackey, B., Prentice, I.C., Steffen, W., House, J.I., Lindenmayer, D., Keith, H., et al. (2013). Untangling the confusion around land carbon science and climate change mitigation policy. Nat Clim Change. 3: 552–557.
43. Needleman, B., Emmot-Maddox, S., Crooks, S., Beers, L., Megonigal, P., Myers, D., et al. (2021). VM0033 Methodology for tidal wetland and seagrass restoration, v 2.0. VCS; Available: https://verra.org/methodology/vm0033-methodology-for-tidal-wetland-and-seagrass-restoration-v2-0/.
44. NC DEQ. (2020). North Carolina Climate Risk Assessment and Resiliency Plan. North Carolina Department of Environmental Quality. 1601 Mail Service Center, Raleigh, NC. https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf.
45. Davidson, N.C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Mar. Freshwater Res. 65, 934–941.
46. Dahl, T.E. & Johnson, C.R. (1991). Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980s. US Dept Interior, Fish and Wildlife Service, Washington, D.C. 28p.
47. Dahl, T.E. (2006). Status and trends of wetlands in the conterminous United States, 1998-2004. US Dept Interior, Fish and Wildlife Service, Washington, D.C. 112 p.
48. Campbell, A.D., Fatoyinbo, L., Goldberg, L., & Lagomasino, D. (2022). Global hotspots of salt marsh change and carbon emissions. Nature, 612(7941), 701-706. https://doi.org/10.1038/s41586-022-05355-z.
49. NCOSBM (North Carolina Office of State Budget and Management). (2021). Population Estimates Timeline and 2020 Census. Raleigh, NC. https://www.osbm.nc.gov/facts-figures/population-demographics/state-demographer/population-estimatestimeline-2020-census.
50. Coverdale, T.C., Brisson, C.P., Young, E.W., Yin, S.F., Donnelly, J.P., & Bertness, M.D. (2014). Indirect human impacts reverse centuries of carbon sequestration and salt marsh accretion. PloS ONE 9(3): e93296. https://doi.org/10.1371/journal.pone.0093296.
51. Schueler, T.R., & Holland, H.K. (2000). The practice of watershed protection; techniques for protecting our nation's streams, lakes, rivers, and estuaries. Center for Watershed Protection Publishers, Ellicott City.
52. Deegan, L.A., Johnson, D.S., Warren, R.S., Peterson, B.J., Fleeger, J.W., Fagherazzi, S., & Wollheim, W.M. (2012). Coastal eutrophication as a driver of salt marsh loss. Nature 490 (7420): 388–392. https://doi.org/10.1038/nature11533.
53. NC DCM (North Carolina Division of Coastal Management) (2015). North Carolina estuarine shoreline mapping project:. 2012 statistical reports. North Carolina Department of Environmental Quality. Morehead City, NC. 109 p.
54. Burdick, S.A. (2018). Effects of bulkheads on salt marsh loss: a multi-decadal assessment using remote sensing. Masters, Duke University. Durham, NC. 34p.
55. Wolfe, R., Zarebicki, P., & Meredith, W. (2021). The evolution of saltmarsh mosquito control water management practices relative to coastal resiliency in the Mid-Atlantic and northeastern United States. Wetlands Ecol Manage 30:1099–1108. https://doi.org/10.1007/s11273-021-09817-5(0123456789().,-volV)(01234567.
56. Lashley, D. (2013). Historic ditching effects on salt marsh structure. GreenVest. Available from: https://www.greenvestus.com/2013/11/15/historic-ditching-effects-salt-marsh-structure/#:~:text=Extensively%20ditched%20salt%20marsh%20systems,%2C%20sulfide%20production%2C%20and%20pH.
57. Bilkovic, D., Mitchell, M., Davis, J., Andrews, E., King, A., Mason, P., Herman, J., Tahvildari, N., & Davis, J. (2017). Review of boat wake wave impacts on shoreline erosion and potential solutions for the Chesapeake Bay. STAC Publication Number 17-002, Edgewater, MD. 68 pp.
58. Liddle, M.J., & Scorgie, H.R.A. (1980). The effects of recreation on freshwater plants and animals: a review. Biological Conservation 17(3): 183-206.
59. National Oceanic and Atmospheric Administration Marine Debris Program. (2016). Report on Marine Debris Impacts on Coastal and Benthic Habitats. Silver Spring, MD: National Oceanic and Atmospheric Administration Marine Debris Program.
60. Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768–771. Doi: 10.1126/science.1260352.
61. Uhrin, A. V., & Schellinger, J. (2011). Marine debris impacts to a tidal fringing-marsh in North Carolina. Marine Pollution Bulletin, 62(12), 2605–2610. Doi: 10.1016/j.marpolbul.2011.10.006.
62. Viehman, S., Vander Pluym, J. L., & Schellinger, J. (2011). Characterization of marine debris in North Carolina salt marshes. Marine Pollution Bulletin, 62(12), 2771–2779. Doi: 10.1016/j.marpolbul.2011.09.010.
63. Paduani, M. (2020). Microplastics as novel sedimentary particles in coastal wetlands: a review. Marine Pollution Bulletin 161:111739.
64. White, E., & Kaplan, D. (2016). Restore or retreat? Saltwater intrusion and water management in coastal wetlands. Ecosystem Health and Sustainability 3(1):e01258.
65. Ury, E.A., Yang, X., Wright, J.P., & Bernhardt, E.S. (2021). Rapid deforestation of a coastal landscape driven by sea level rise and extreme events. Ecological Applications. https://doi.org/10.1002/eap.2339.
66. NC DEQ. (2021). North Carolina Coastal Habitat Protection Plan 2021 Amendment. Department of Environmental Quality, Raleigh, NC. Pp.101-102.
67. Cahoon, D.R., & Guntenspergen, G.R. (2010). Climate change, sea-level rise, and coastal wetlands. National 752 Wetlands Newsletter 32:8-12.
68. Kolker, A.S., Kirwan, M.L., Goodbred, S.L., & Cochran, J.K. (2010). Global climate changes recorded in coastal 877 wetland sediments: empirical observation linked to theoretical predictions. Geophys. Res. Lett. 37, 878 L14706.
69. Jørgensen, S.E., & Fath, B.D. (2011). 10-Structurally dynamic models. In: Sven Erik J, Brian DF (Eds.), 863 Developments in Environmental Modelling, vol. 23. Elsevier, Amsterdam, pp. 309–346.
70. Nunez, M.K., Zhang, Y., Herman, J., Reay, W., & Hershner, C. (2020). A multi-scale approach for simulating tidal marsh evolution. Ocean Dynamics. 70. 10.1007/s10236-020-01380-6.
71. Mariotti, G., & Carr, J. (2014). Dual role of salt marsh retreat: Long-term loss and short-term resilience. Water Resources Research. 50. 10.1002/2013WR014676.

72. Morris, J.T., Barber, D.C., Callaway, J.C., Chambers, R., Hagen, S.C., Hopkinson, C.S., Johnson, B.J., Megonigal, P., Neubauer, S.C., Troxler, T., & Wigand, C. (2016). Contributions of organic and inorganic matter to 948 sediment volume and accretion in tidal wetlands at steady state. Earth's Future 4(4):110-121. 949 https://doi.org/10.1002/2015EF000334.

73. Boon, J.D., & Mitchell, M. (2015). Nonlinear Change in Sea Level Observed at North American Tide 740 Stations. Journal of Coastal Research 31(6):1295–1305. https://doi.org/10.2112/JCOASTRES-D-15-741 00041.1.

74. Currin, C., Davis, J., & Hilting, A. Decadal changes in surface elevation confirm vulnerability of microtidal marshes to sea level rise in North Carolina. In Press.

75. Esteves, L.S. (2016). Coastal Squeeze. In: Kennish, M.J. (eds) Encyclopedia of Estuaries. Encyclopedia of Earth Sciences Series. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-8801-4_405.

76. North Carolina Land of Water. (2023). The NC LOW Coastal System. Northeastern North Carolina Region. Available from: http://www.nclandofwater.org/regions/.

77. National Oceanic and Atmospheric Administration (NOAA). (2023). Sea Level Rise Viewer. NOAA. Available from: https://coast.noaa.gov/slr/.

78. Martinich, J., Neumann, J., Ludwig, L., & Jantarasami, L. (2013). Risks of sea level rise to disadvantaged communities in the United States. Mitigation and Adaptation Strategies for Global Change, 18(2), 169–185. https://doi.org/10.1007/s11027-011-9356-0.

79. Hardy, R. D., Milligan, R. A., & Heynen, N. (2017). Racial coastal formation: The environmental injustice of colorblind adaptation planning for sea-level rise. Geoforum, 87, 62-72. https://doi.org/10.1016/j.geoforum.2017.10.005.

80. Hardy, R. D., & Hauer, M. E. (2018). Social vulnerability projections improve sea-level rise risk assessments. Applied Geography, 91, 10-20. https://doi.org/10.1016/j.apgeog.2017.12.019.

81. Bhattachan, A., Jurjonas, M. D., Moody, A. C., Morris, P. R., Sanchez, G. M., Smart, L. S., Taillie, P. J., Emanuel, R. E., & Seekamp, E. L. (2018). Sea level rise impacts on rural coastal social-ecological systems and the implications for decision making. Environmental Science & Policy, 90, 122-134. https://doi.org/10.1016/j.envsci.2018.10.006.

82. Handwerger, L., Sugg, M., & Runkle, J. (2021). Present and future sea level rise at the intersection of race and poverty in the Carolinas: A geospatial analysis. The Journal of Climate Change and Health, 3, 100028. https://doi.org/10.1016/j.joclim.2021.100028.

83. Kahrl, A. W. (2014). The Sunbelt's sandy foundation: Coastal development and the making of the modern South. Southern Cultures, 20(3), 24-42. https://doi.org/10.1353/scu.2014.0028.

84. Atteridge, A., & Remling, E. (2018). Is adaptation reducing vulnerability or redistributing it? WIREs Climate Change, 9, 1-16, e500. https://doi.org/10.1002/wcc.500.

85. Howell, J., & Elliott, J. R. (2019). Damages done: The longitudinal impacts of natural hazards on wealth inequality in the United States. Social Problems, 66, 448–467. https://doi.org/10.1093/socpro/spy016.

86. US EPA. (2021). Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts (Report No. EPA 430-R-21-003). Retrieved from www.epa.gov/cira/social-vulnerability-report.

Photo: NCCF

6. Appendices

6.1. Appendix A. Stakeholder Workshop Summaries.

Salt Marsh Workshop – August 19, 2022

- Held in Newport, NC
- Representatives from DCM, DMF, Duke University, East Carteret Collaborative, ECU, NC Coastal Federation, NC Coastal Reserve, NOAA, NRCS, Southern Environmental Law Center NC, Town of Beaufort, UNCW
- Discussed starting points and key components for development of NC SMAP, including the timeframe, SLR scenario, scope, etc.

Salt Marsh Restoration Workshop – August 22, 2023

- Held in Hammocks Beach State Park in Swansboro, NC
- Representatives from APNEP, CCC, DCM, DMF, DWR, ECU, ENCSL, MCB Camp Lejeune, Native Shorelines, NC Coastal Federation, NC Coastal Reserve, NC Sea Grant, NC State Parks, NC WRC, NERRS, NOAA, Sandbar Oyster Company, UNC-IMS, UNCW
- Discussed marsh restoration-focused recommendations for the NC SMAP

Salt Marsh Migration Workshop – August 29, 2023

- Held in Wanchese, NC
- Representatives from Albemarle RC&D, Dare Soil & Water Conservation District, DCM, ECU-CSI, NPS, NC Coastal Federation, NC Coastal Reserve, NC State Parks, NC WRC, NERRS, TNC, USACE, USFWS
- Discussed marsh migration-focused recommendations for the NC SMAP

Figure 1. Participant discussions during the Salt Marsh Workshop held in Newport, NC in August 2022. Image Source: NCCF.

6.2. Appendix B. North Carolina Salt Marsh Projections through 2050.

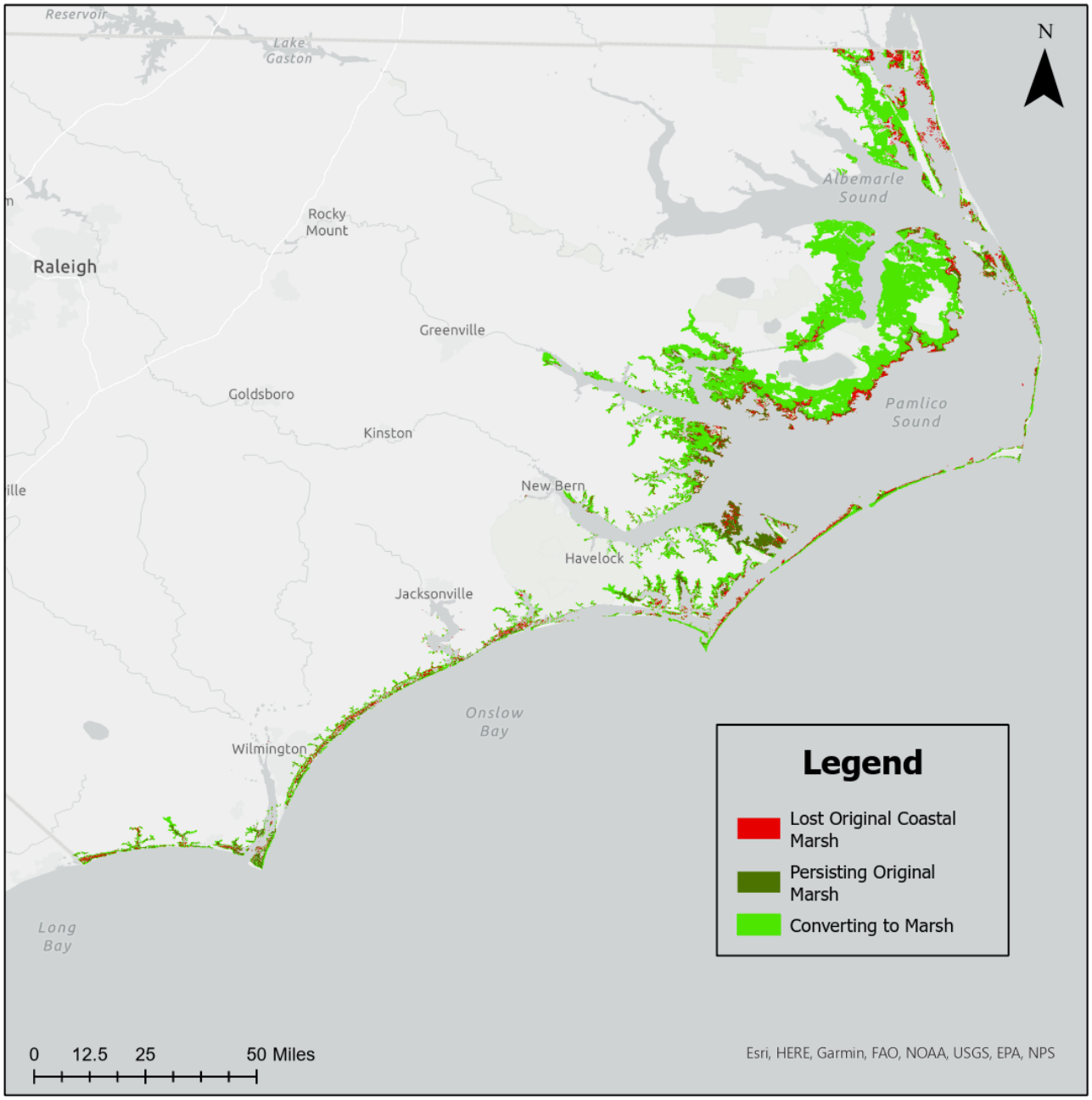


Figure 1. North Carolina salt marsh projections through 2050.

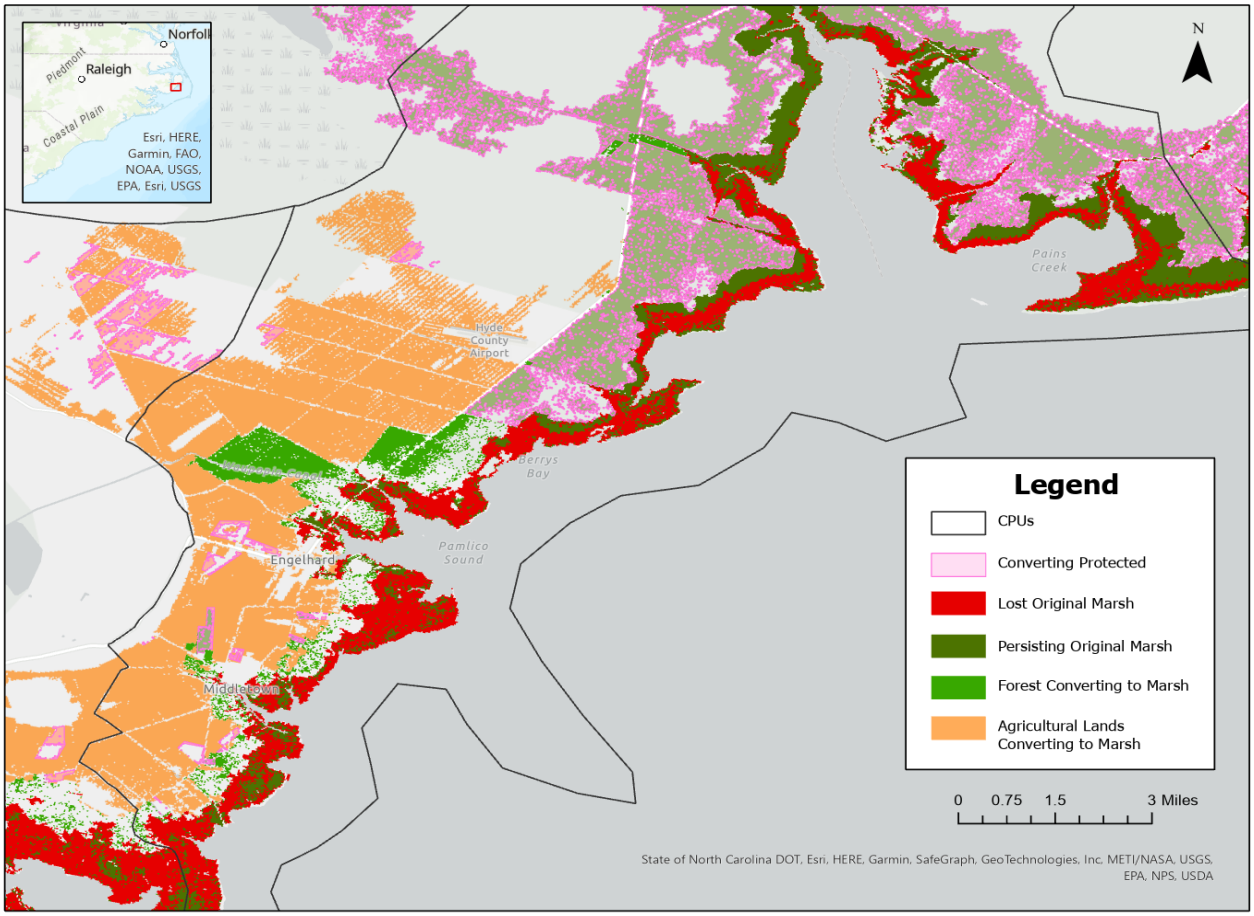


Figure 2. North Carolina salt marsh projections through 2050 throughout Pamlico Sound – Hyde County.

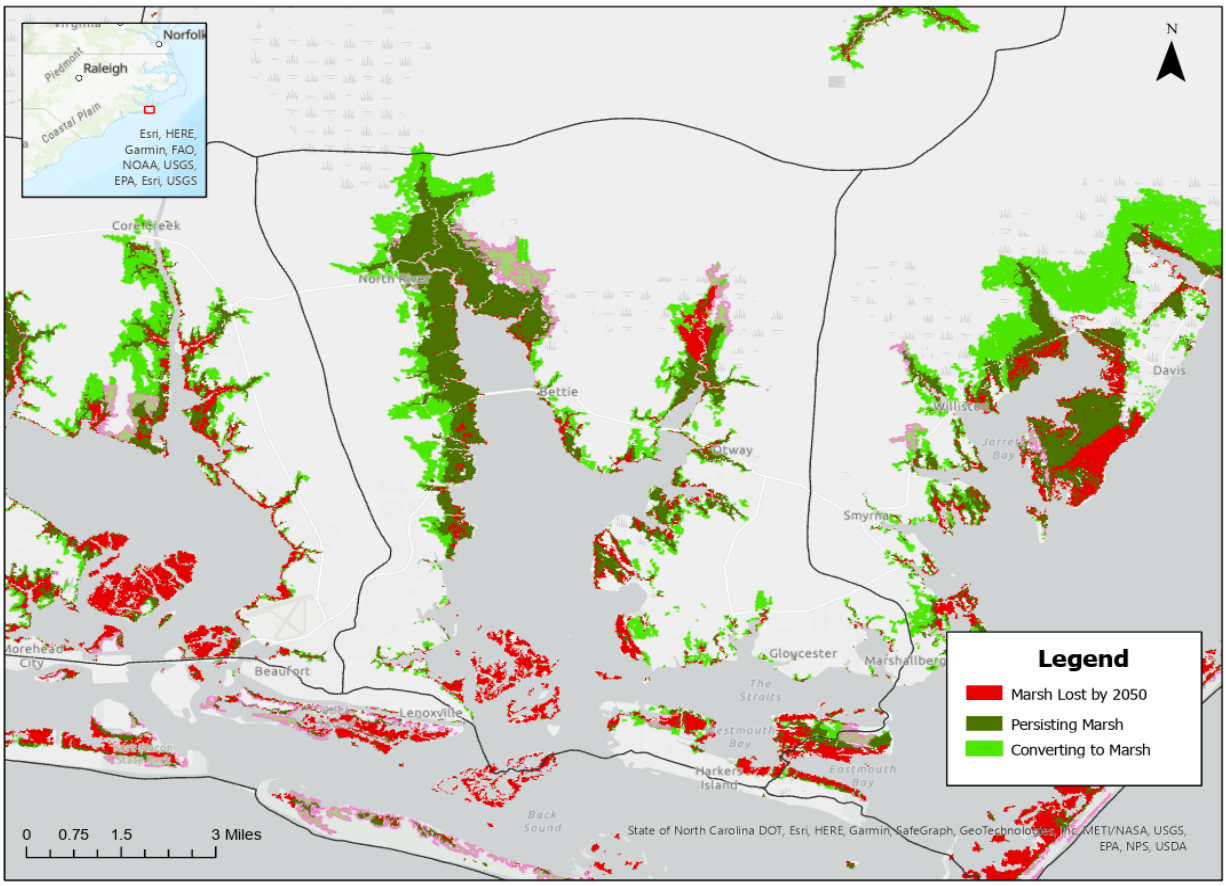


Figure 3. North Carolina salt marsh projections through 2050 throughout North River – Carteret County.

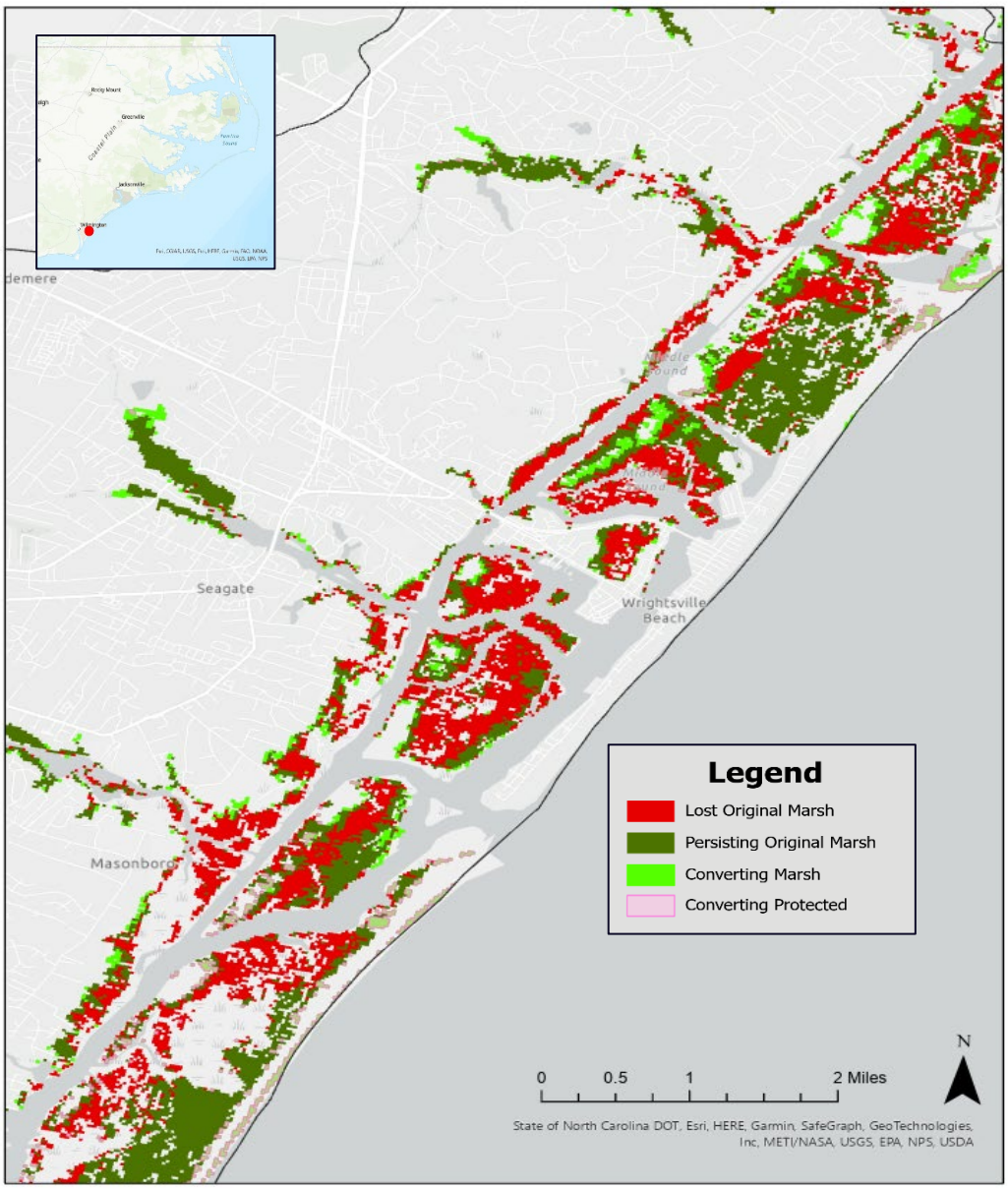


Figure 4. North Carolina salt marsh projections through 2050 throughout Wrightsville Beach – New Hanover County.

6.3. Appendix C. North Carolina Salt Marsh Projections through 2050 by County.

Table 1. North Carolina salt marsh projections through 2050 by acreage per county, in order from most acreage loss to most acreage gain. Data sourced from Warnell, et al. 2022[37].

County	[1]Current Acreage	[2]2050 Acreage	Difference	Gain or Loss	Percent Change
Onslow	10,095	5,924	-4,170	Loss	-41%
Carteret	55,715	52,339	-3,376	Loss	-6%
Brunswick	15,135	12,924	-2,211	Loss	-15%
Pender	5,674	3,522	-2,152	Loss	-38%
New Hanover	6,822	4,975	-1,846	Loss	-27%
Perquimans	0.2	0.00	-0.2	Loss	-100%
Pasquotank	36	645	608	Gain	1,667%
Craven	1,547	2,179	632	Gain	41%
Currituck	24,783	26,334	1,551	Gain	6%
Camden	1,468	6,600	5,132	Gain	349%
Pamlico	20,680	28,315	7,635	Gain	37%
Beaufort	7,497	24,264	16,767	Gain	224%
Tyrrell	1,191	42,996	41,805	Gain	3,510%
Dare	28,923	81,025	52,102	Gain	180%
Hyde	38,450	104,322	65,872	Gain	171%

[1]Current acreage was calculated by adding persisting original marsh acreage to lost original marsh acreage;
[2]2050 acreage was calculated by adding persisting original marsh acreage to migrated coastal marsh acreage (i.e., forested lands converting to marsh) and ag to marsh acreage (i.e., agricultural lands converting to marsh).

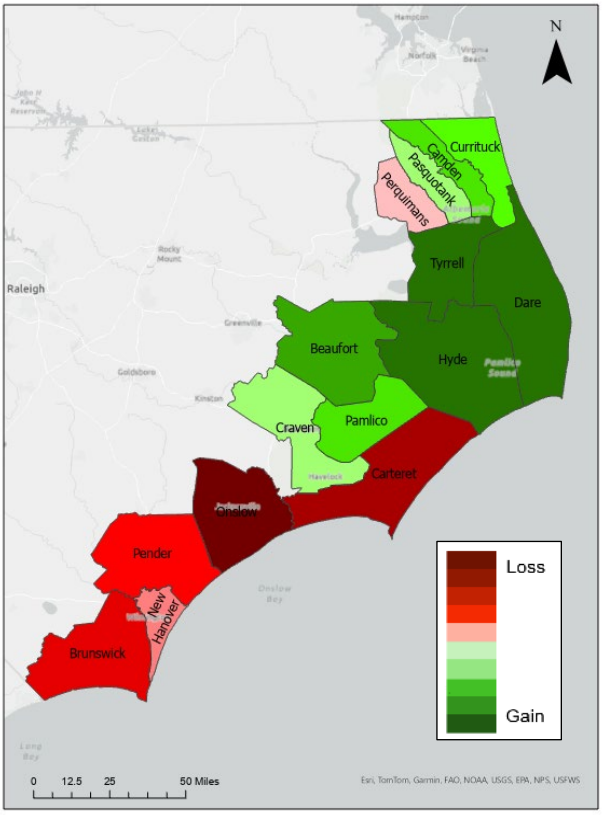


Figure 1. North Carolina salt marsh projections through 2050 per coastal county.

6.4. Appendix D. Conservation Planning Units.

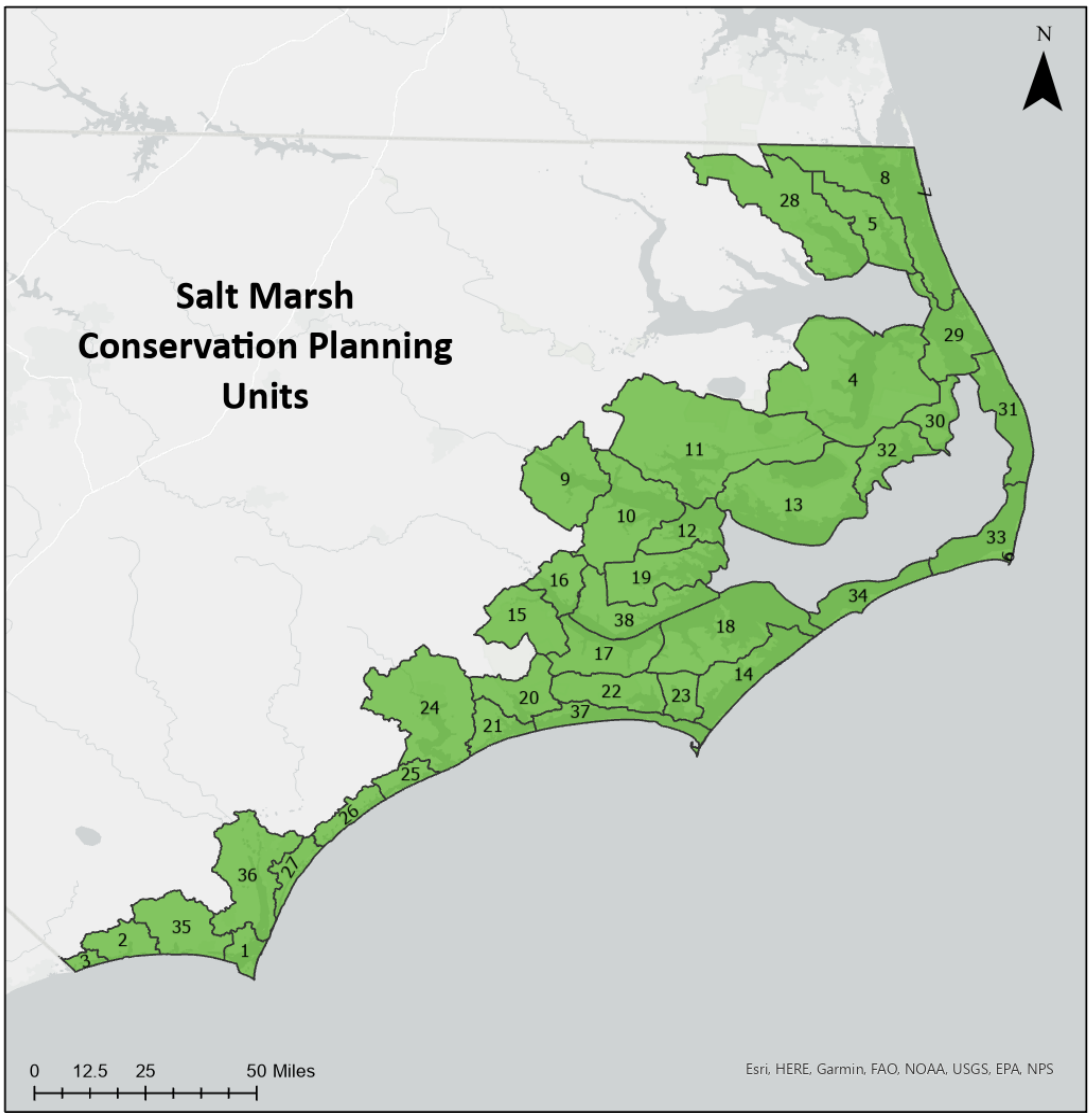


Figure 1. North Carolina salt marsh projections through 2050 per conservation planning unit.

Table 1. North Carolina salt marsh projections through 2050 per conservation planning unit. Data sourced from Warnell, et al. 2022[37].

No.	CPU Watershed	[1]Current Acreage	[2]2050 Acreage	Difference	Gain or Loss	Percent Change
1	Lower Cape Fear River	7,371	6,761	-610	Loss	-8%
2	Shallotte River	2,367	1,839	-528	Loss	-22%
3	Little River	2,605	1,245	-1,360	Loss	-52%
4	Alligator River	3,568	86,523	82,955	Gain	2,325%
5	North River Game Land	4,302	15,324	11,022	Gain	256%
6	Hatteras Island	93	98	5	Gain	6%
7	Northern Outer Banks	14	21	7	Gain	49%
8	Currituck Sound	21,315	15,581	-5,734	Loss	-27%
9	Upper Pamlico River	625	3,113	2,489	Gain	398%
10	Middle Pamlico River	1,967	3,755	1,788	Gain	91%
11	Pungo River	10,357	39,802	29,446	Gain	284%
12	Lower Pamlico River	8,336	13,758	5,422	Gain	65%
13	Lake Mattamuskeet	22,887	53,914	31,027	Gain	136%
14	Core Sound	13,983	11,384	-2,599	Loss	-19%
15	Lower Trent River	49	24	-25	Loss	-51%
16	Upper Broad Creek	547	1,092	545	Gain	100%
17	Neuse River-Cherry Point	1,221	1,390	169	Gain	14%
18	Lower Neuse River-Cedar Island	26,655	25,346	-1,309	Loss	-5%
19	Bay River-Jones Bay	11,065	14,724	3,659	Gain	33%
20	White Oak River	919	664	-255	Loss	-28%
21	Queen Creek-Bogue Sound	5,445	2,926	-2,520	Loss	-46%
22	Newport River	4,847	5,831	985	Gain	20%
23	North River	4,375	4,967	592	Gain	14%
24	New River	2,042	1,287	-755	Loss	-37%
25	North Topsail Beach	3,059	1,926	-1,133	Loss	-37%
26	Topsail Beach	5,971	3,736	-2,235	Loss	-37%
27	Wrightsville Beach	5,056	3,569	-1,487	Loss	-29%
28	Pasquotank River	121	1,551	1,430	Gain	1,187%
29	Croatan-Roanoke Sound-Kitty Hawk Bay	9,552	14,448	4,896	Gain	51%
30	Croatan Sound-Stumpy Point Bay	3,146	12,189	9,043	Gain	287%
31	Roanoke Sound-Oregon Inlet	8,610	6,022	-2,588	Loss	-30%
32	Long Shoal River-Hyde Co Airport	9,194	25,954	16,760	Gain	182%
33	Pamlico Sound-Hatteras Island	1,974	1,670	-303	Loss	-15%
34	Pamlico Sound-Ocracoke Inlet	4,342	3,915	-427	Loss	-10%
35	Lockwoods Folly River	3,009	3,311	303	Gain	10.%
36	Upper Cape Fear River	741	581	-161	Loss	-22%
37	Bogue Sound	2,861	2,408	-453	Loss	-16%
38	Neuse River-Minnesott Beach	3,418	3,864	447	Gain	13%
Total		218,004	396,510	178,506	Gain	82%

[1]Current acreage was calculated by adding persisting original marsh acreage to lost original marsh acreage;
[2]2050 acreage was calculated by adding persisting original marsh acreage to migrated coastal marsh acreage (i.e., forested lands converting to marsh) and ag to marsh acreage (i.e., agricultural lands converting to marsh).

6.5. Appendix E. Non-exhaustive list of existing efforts, programs, and tools with potential synergies with the North Carolina Salt Marsh Action Plan.

Title	Description	[1]Lead(s)
Guidance for Considering the Use of Living Shorelines 2015	Guidance intended to provide information on NOAA's perspective and roles regarding living shorelines implementation.	NOAA LSW
2022-2026 Estuarine Shoreline Strategy	Aims to better understand and manage estuarine shorelines through an integrated approach of planning, permitting, education, and research.	NCDCM
NC Resilience Exchange	Helps local and state leaders in North Carolina understand their community's climate resilience needs, identify appropriate actions and find the resources to implement solutions.	NCORR
NC SET Community of Practice	A voluntary and unfunded partnership among stakeholders who have either installed Surface Elevation Tables in coastal wetlands or who rely on data.	NC CR&NERR, NCSG, NOAA NCCOS
NC Resilient Coastal Communities Program	Aims to facilitate a community-driven process for setting coastal resilience goals, assessing existing and needed local capacity, and identifying and prioritizing projects to enhance community resilience to coastal hazards.	NCDCM
2024 Efficient Permitting Roadmap	A guide to the regulatory process for sediment management on the North-Central California Coast.	NCCCSCC
Wetland Monitoring and Assessment Team	Provides the partnership with technical guidance for monitoring and assessing a subsystem of the regional ecosystem: wetland vegetation and associated fauna.	APNEP
Currituck Sound Coalition	Fosters collaboration among diverse partners on ecosystem restoration and conservation with members working together to advance nature-based solutions.	NC Audubon
Regions Innovating for Strong Economies and Environment Program	Aims to support resilience by providing coaching and technical assistance to regional partners to support community vulnerability assessments, identify priority actions to reduce risk and enhance resilience in their region, and develop paths to implementation.	NCORR
Saltwater Intrusion and Sea Level Rise	Conduct convergence research by building a connective intellectual network and an integrated conceptual scaffolding to rapidly expand our capacity to forecast and prepare for SWISLR impacts throughout the rural communities of the Atlantic and Gulf coasts of North America.	Duke
NC Flood Resiliency Blueprint	Statewide initiative to develop an online-decision support tool and associated planning to address flooding for communities in North Carolina's river basins.	NCDEQ
NC Living Shoreline Steering Committee	Brings together governmental agencies, NGOs, universities, suppliers, contractors, and engineers to communicate and collaborate on living shoreline education and outreach, implementation and incentives, policy, and research to increase the use of living shorelines coastwide.	NCCF, APNEP
Building Capacity for Community Resilience and Ecosystem Enhancement	Community capacity building and planning within vulnerable coastal communities to identify, prioritize, and advance projects that protect and enhance existing or conserve potential future salt marsh habitat and build coastal resilience. Develop a suite of 20-25 nature-based solutions is ready for site assessment and preliminary design across NC, SC, GA, and NE FL.	NCCF, NCDCM
Pathways to Resilience: Ensuring a Future for Tidal Wetlands	NC Reserve is 1 of 6 participating in a NERRS project to create a pipeline of tidal wetland migrations projects. Stage 1 of the larger project focused on identifying and engaging community partners and determining future geographic scope.	NC CR&NERR
Wetlands Mapping Interagency Workgroup	Interagency Wetlands Mapping Workgroup for planning and implementing conservation actions that protect coastal wetlands and the ecosystem services they provide.	NCDMF, NCDEQ

[1] APNEP - Albemarle-Pamlico National Estuary Partnership; Duke - Duke University; NC CR&NERR - NC Coastal Reserve and National Estuarine Research Reserve; NCCCSCC - North-Central California Coastal Sediment Coordination Committee; NCCF - NC Coastal Federation; NCDCM - NC Division of Coastal Management; NCDEQ - NC Department of Environmental Quality; NCDMF - NC Division of Marine Fisheries; NCORR - NC Office of Recovery and Resiliency; NCSG - NC Sea Grant, NOAA - National Oceanic and Atmospheric Administration; NOAA LSW - NOAA Living Shorelines Workgroup; NOAA NCCOS - NOAA National Centers for Coastal Ocean Science

6.6. Appendix F. Proposed Annual Strategic Plan Outline.

1. Introduction – Purpose and Scope
2. The Current State of Salt Marsh in North Carolina (1-2 paragraphs to set the stage for priority objectives, actions, and related projects identified below)
3. Maps
    a. Coastwide and county by county or watershed by watershed showing current salt marsh and expected marsh migration areas
4. Phases of Implementation (by county or watershed)
    a. Strategy 1: Advance Salt Marsh Conservation and Restoration
        i. Identify priority objectives and actions from the SASMI plan
        ii. Identify priority marsh areas to protect or restore
        iii. Best pathway or method to restore or protect each priority area identified
        iv. Set goals for protection and for restoration (e.g., # acres restored)
        v. Identify partners to lead each identified action
    b. Strategy 2: Facilitate Salt Marsh Migration
        i. Identify priority objectives and actions from the SASMI plan
        ii. Identify priority marsh migration corridors to be conserved and hydrologic barriers to be removed/retrofitted
        iii. Best pathway or method to conserve each priority area identified
        iv. Set goals for migration corridors conserved (e.g., # acres conserved, barriers removed, etc.)
        v. Identify partners to lead each identified action
    c. Strategy 3: Incorporate Crosscutting Approaches – Prioritization of actions, related work to address those actions, pathways and players for each crosscutting approach identified in the regional plan
        i. Policy changes
        ii. Cultural and community engagement
        iii. Communication, education, and engagement
        iv. Funding (including state and local funding sources)
5. Tracking Progress
    a. Identify key metrics for success
        i. In coordination with the partnership council
    b. Systematic monitoring of key metrics against goals
    c. Adaptive management
        i. Timetable and process for updating and adapting the roadmap
6. Change Analysis
    a. What will the impact be if these projects/policies aren't implemented?
7. Other (Appendix?)
    a. Prioritization methodology